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MINERAL RESOURCES OF CHINA.

PART I.

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INTRODUCTION.

A mining proposition in China is unlike one in any other country; there's nothing new about it. American mines are new and so are methods. In Europe new methods are applied to old mines. But in China, mines and methods are those of the ancestral Chinese. Inhabited for several thousand years by a people skilled in the use of metals, China has but little unprospected territory. Practically all her metalliferous deposits are known and have been worked to the level where pumping became necessary; but they have not been worked with effective appliances for deep mining or with an intelligent understanding of ore deposits, and their future productiveness depends upon the application of modern machinery, business methods, and scientific knowledge.

The Chinese have long produced all the commoner metals: iron, copper, zinc, lead, tin, mercury, silver, and gold. They are industrious and capable miners and skilled metallurgists according to their empirical methods. The Westerner need not expect to teach them anything along the lines they have developed; but in chemistry, mechanics, and geology, he can teach them much and he will find them eager to learn till they become his equals.

They will never become his superiors in invention if the past of the races is any guide to their future.

Present conditions do not favor profitable mining in China, whether by Chinese or foreign capital. Labor at twelve to eighteen cents a day, coal at a nominal price at the mine, water transportation at very low rates may lead the foreigner to expect large returns in comparison with mines in countries less favored in these respects, but prohibitive costs for timber, lack of transportation to water, fluctuations in money values, numerous taxes and official perquisites squeeze the profit out.

The greatest material lack in relation to mineral resources in China is timber. The Chinese, aided in the north by a severe climate, and in the south using charcoal for smelting, have destroyed the forests and shrubbery and almost all natural herbage except hardy grasses. Their effectiveness in this regard is well illustrated by the condition of the Wu-tai-shan, an extensive mountain range in the province of Shan-si rising to altitudes above 8,000 feet, which they first settled with any considerable population something less than 200 years ago. Prior to that time the region had been inhabited by numerous monks attached to monasteries of Tibetan associations, and the extensive forests had not been cut, but by promotion of immigration from eastern China the forests began to disappear and the mountains are now as bare as a desert. In Manchuria, especially in the eastern mountains, there are said to be extensive forests of large pine which are, however, being very rapidly cut. Although the Chinese have not attained the proficiency of the American lumberman, it is not probable that the remaining timber in the remotest regions will last a half century.

On the accompanying maps the principal water routes are emphasized, but almost every stream in China is navigated. Transportation by water extends to small swift streams, the Chinese being very skillful in running rapids and coolies numerous for tracking up them. Away from streams wretched cart or wheel-barrow tracks are the best means even in the plains, and packing by men or animals the only means in the hills. The possible radius of such carriage is very short for most materials.

The money of the country is still silver bullion and copper cash, which vary constantly in value. An American engineer in charge of a coal mine regularly paid off a large force of men in the copper cash, the coin of the country, of which 1,000 equal 1 tael, nominally. But when he wanted to buy cash the local bankers put the price to 800 for 1 tael and when a few days later his men spent cash, the bankers dropped the price to 1,200 per tael. Remonstrance was vain. The laws of supply and demand are inexorable. But the American knew something about banking too. Having laid in several tons of copper cash and a large amount of silver, he issued notes redeemable for fixed amounts, and so controlling the situation saved his company.

Taxation in China is according to an extremely antique and arbitrary method, but it is very searching and ingenious. The likin tax, levied on internal commerce at every boundary of province, district, city, or other convenient point, is still strongly entrenched in spite of treaty agreement for its abolition, and is likely to be applied anywhere at any time. It throttles commerce.

Official activity may also take other forms, as appears from the following: "Owing to financial difficulties in the Kuangtung province the Viceroy has given instructions to the director of the bureau of agriculture and labor to devise means to raise capital and float companies to work all the mines in the Kuangtung province." [1]

Reliable statistics of the production of metals and other mineral products in China are not to be found. Figures of amounts exported are available through the Imperial Chinese customs, but they do not represent the total exports, especially of gold, and they bear no known relation to the internal consumption.[2] That China has been able to produce the materials needed by her enormous population in the development of her arts and industries for four thousand years or more is the best evidence of the wealth she has had. That she has practically exhausted the

[1] Daily Consular and Trade Reports, Dept. of Commerce and Labor, Washington, D. C., April 6, 1907.

[2] See "Manchuria, Its People, Resources, etc.," by Alex. Hosie, 1901, especially the chapter on Trade.

superficial part of her deposits is probable. That the ore bodies below water level generally remain is known.

There are no official geologic or mineral surveys of China and consequently no general sources of information. From Kingsmill and Richthofen to the present time travellers, engineers, and geologists have published their observations in many individual books and separate articles. The best general index to them is the "Bibliotheca Sinica," [3] and it may be supplemented by references in the various books to which it leads. North China is far more accessible and much better known than southern or western China, yet such has been the daring and persistence of travellers since the time of the Jesuits early in the eighteenth century that no considerable feature of the empire has escaped a visit and description. In writing this summary of information I have not attempted an exhaustive or balanced treatment, but have aimed to bring together the principal available facts relating to the geology of China and its bearing on the mineral resources.

GENERAL OBSERVATIONS.

China proper, the country here discussed, has an area of about 1,400,000 square miles and is bounded by Korea, Siberia, the Chinese provinces of Mongolia and Tibet, India, Tonkin and the Pacific. It is that half of the Chinese empire which supports most of the Chinese people and is so conditioned by geographical position and climate that it is or is likely to become an important factor in the world's affairs.

The country is more generally mountainous than may commonly be supposed. The alluvial plains of the Yang-tzi and Yellow (Huang-ho) rivers, together with those of Manchuria, comprise about 200,000 square miles. The remaining 1,200,000 are hilly or mountainous. General summit altitudes range from 3,000 feet in southwestern China up to 12,000 in the ranges of central China, and 27,000 in eastern Tibet. At the foot of the

[3] "Bibliotheca Sinica, a bibliographic dictionary of works on China," by Henri Cordier, 2d edition, Paris, 1904.

great Tibetan heights is the remarkable depression of Ssi-ch'uan, which lies but 1,500 feet above sea or less.[1]

The Yellow River (Huang-ho), known on account of its floods as the Grief of China, is not navigable above points near the head of its delta cone. The Yang-tzi, the Girdle of China, is navigable for steamers to I-ch'ang, 960 miles from its mouth, presents grave but not insuperable dangers to navigation in the rapids of its gorges for 100 miles above I-ch'ang, and is again navigable for river steamers for 300 miles further to Chung-king, the metropolis of the western provinces. Hankow being on this great river at the crossing of the Canton-Peking trunk railroad at the convergence of trade routes along which railroads must eventually be built from northwest, southwest, and southeast, is the future Chicago of China.

There is no one region which may be characterized as especially rich in minerals. The mineral resources have been determined by geologic conditions and are widely distributed accordingly in provinces in which circumstances were favorable. Broadly speaking, there are two radically different sets of conditions: First, that in which the sedimentary rocks younger than the very old schists have not been metamorphosed in any appreciable degree, as in North China; second, that in which the sedimentary rocks of relatively modern date as well as the older ones have been more or less extensively metamorphosed and intruded by igneous rocks, as in South China.

In regions characterized by the former conditions the principal valuable minerals are gold in the old rocks and in placers derived from them, and coal among the sedimentary beds; whereas in the provinces where metamorphism and igneous intrusion prevail, metalliferous deposits, especially of gold, tin and copper, are more or less widely distributed, but individual coal fields, though numerous, are presumably not extensive.

A rough likeness of geologic conditions might be traced between North China and the eastern United States on the one hand and South China and the western states on the other. The

[1] "Research in China," Vol. II., Plate 7, hypsometric map, by Bailey Willis, Carnegie Institution of Washington, publication No. 54, 1907.

coal-fields of Shan-si and those of Pennsylvania, the gold-bearing rocks of Chi-li and those of the Appalachian mountains have resemblances. The Sierra Nevada and the Coast Ranges may be compared with the Tsin-ling range of Shen-si and perhaps with the mountains of Yün-nan, Kui-chou and Kuang-si.

Taking a nearer view of the geologic conditions in their bearing on mineral resources we may distinguish the several provinces which are separately discussed in the following pages, namely: North China, Middle Yang-tzi region, Ts'in-ling mountains, Basin of Ssi-ch'uan, and South China.

I. NORTH CHINA.

North China comprises the provinces of Manchuria, Chili, Shan-si, Shan-tung, and Kiang-su. Approximately half its area is alluvial plain, built up by the Huang-ho and its distributaries and in Manchuria by the Liau-ho. The other half is mountainous. The heights are above 5,000 feet in general and 10,000 feet is the greatest. The mountains are bare. There are scarcely any trees except in Manchuria where some forests of pine still remain. The valleys are deeply filled and the rivers, which are sunk in canyons near their heads, wander in wide gravel plains among the foothills.

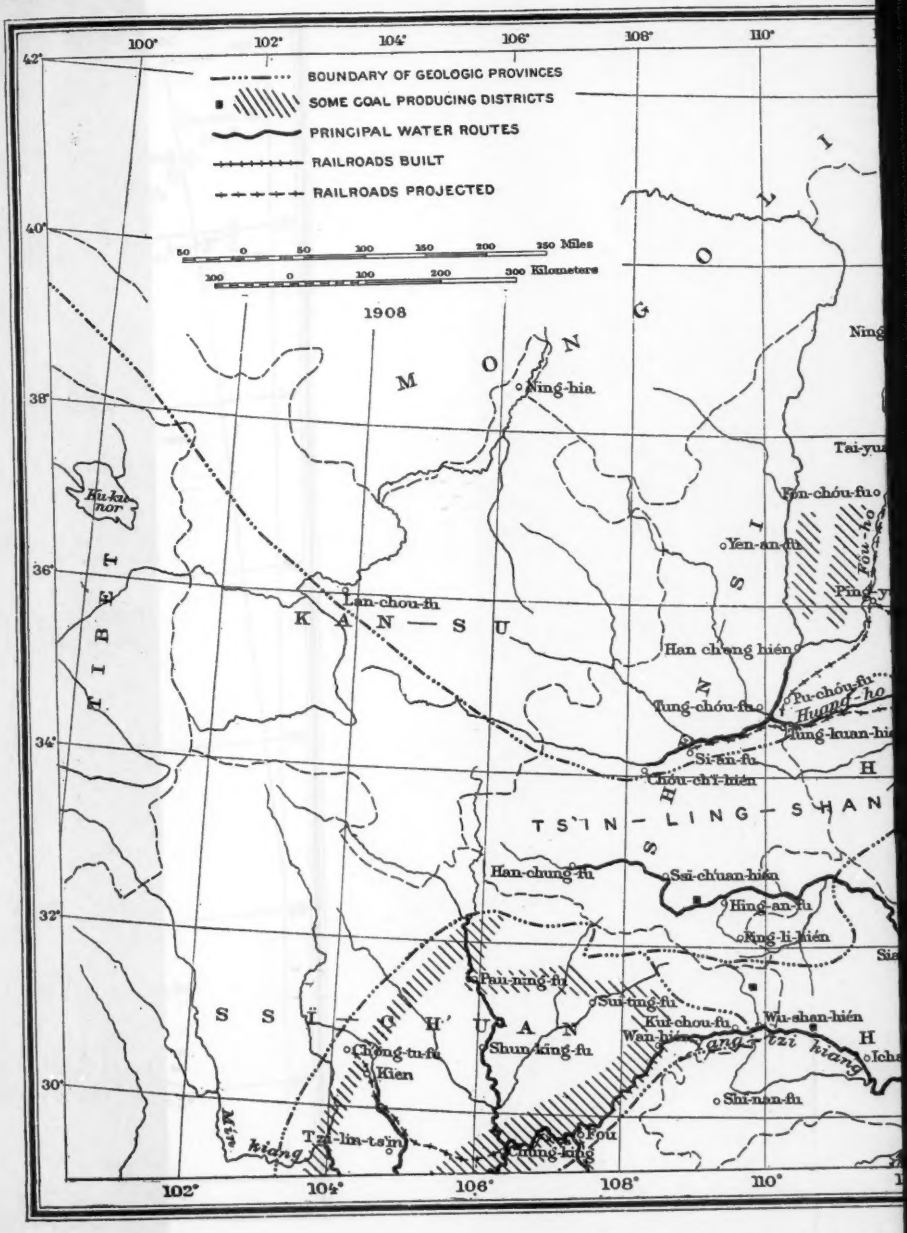
The rocks of North China are schist, gneiss and granite (*Pre-Cambrian*); limestone and shale (*Pre-Cambrian* and *Cambro-Ordovician*); coal-bearing shale and sandstone (*Carboniferous*); barren reddish sandstones (*Permo-Carboniferous*); higher coal measures (*Jurassic*); volcanics (*Mesozoic*); and loess and gravel (*Quaternary*). Their systematic relations are expressed in the following list, which is arranged under mineral products in the order of age of the geologic series, the oldest first.

GOLD-BEARING ROCKS.

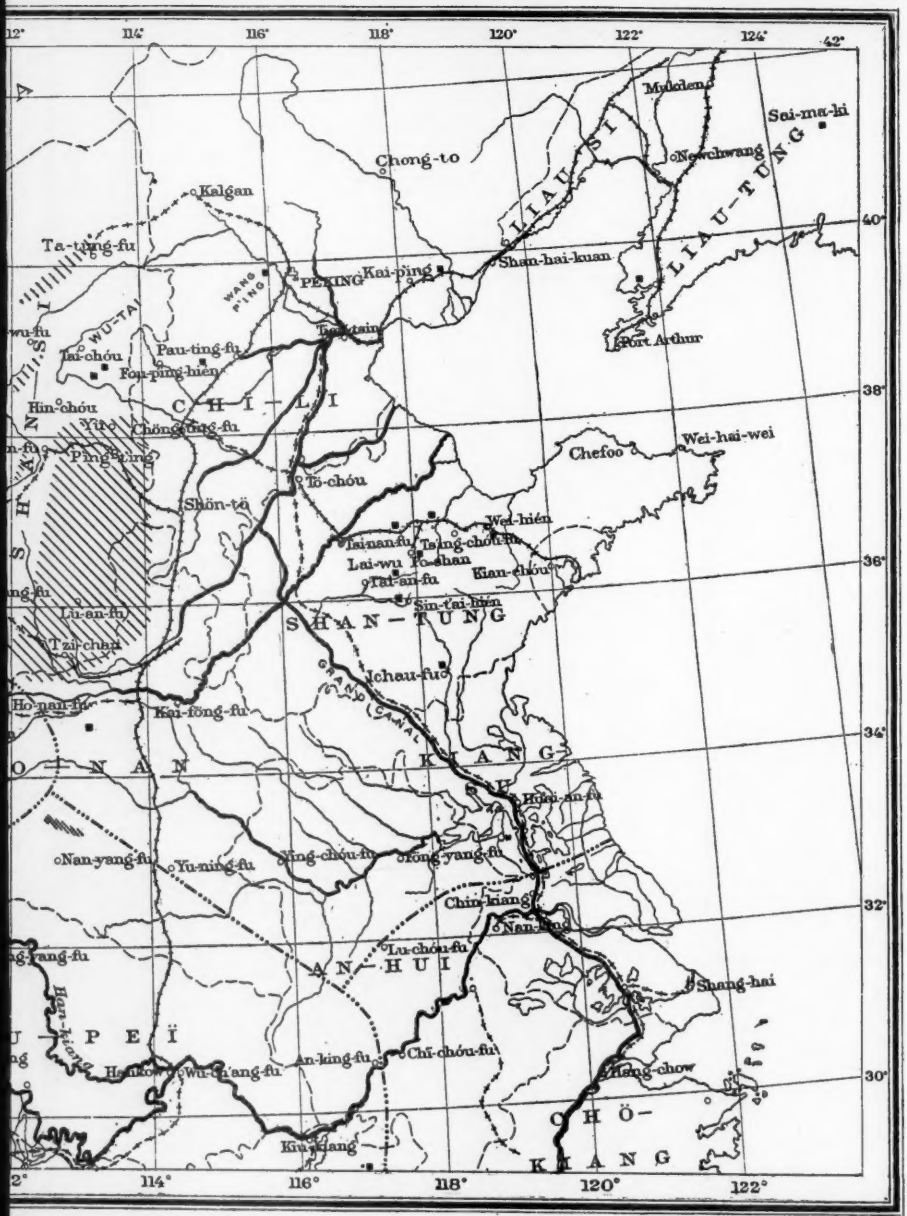
(So-called Archean.)

The principal gold-bearing rocks of North China are schist, gneiss, and granite, all ancient metamorphic rocks, derived in

PLATE I



MAP OF NORTH A



ND CENTRAL CHINA

large part from igneous masses, but in some part originally sedimentary. They resemble the Laurentian of Canada. The valuable metals occur in true fissure and gash veins[1] in quartz, with sulphides of iron, lead, copper, and zinc.

METAMORPHIC IRON ORE FORMATIONS.

(Early Pre-Cambrian.)

The Wu-tai-shan of northern Shan-si is a mountain range composed chiefly of very old sedimentary rocks, intruded by igneous masses, and strongly metamorphosed. The resulting schists and quartzites resemble the Huronian of Canada. Certain quartzite and jaspery beds carry hematite and magnetite and remind one of the lean silicious iron ores of Lake Superior. The occurrence of richer iron ore deposits is not known but is possible in this district and elsewhere where these ancient rocks are exposed. The formations have not been traced or prospected. The typical locality is described by von Richthofen[2] and also by Willis and Blackwelder.[3]

SILICIOUS LIMESTONES.

(Late Pre-Cambrian.)

There is a late pre-Cambrian series of limestones limited in occurrence, so far as now known, to western Shan-si and Chi-li and in certain districts interbedded with much slate and quartzite, which may be distinguished from the Paleozoic limestones of the same areas chiefly by the masses of chert they contain. They have a thickness estimated at 5,000 feet and constitute conspicuous mountain ridges. They are not known to contain any valuable minerals, unless they form the country rock of the silver-lead deposits near Ch'öng-tö (Je-hol) Chi-li.[4]

[1] "Metal Mining in the Provinces of Chi-li and Shan-tung, China," by H. C. Hoover, *Inst. of Mining and Metall. Trans.*, Vol. VIII., 1899–1900, p. 327.

[2] "China," Vol. II., pp. 367 and 376.

[3] "Researches in China," Vol. I., pp. 99 and 157; Vol. II., p. 4; general map. Plate I.; detailed maps, Atlas Sheets D1 and C1.

[4] Hoover, *op. cit.*, p. 329.

LIMESTONES AND SHALES.

(Early Paleozoic.)

More or less thick-bedded gray limestone, which is interbedded with green shale in the lower part and is in some beds conglomeratic and frequently fossiliferous, is of widespread occurrence in North China. The base of the series is a conspicuous red shale, about 500 feet thick. The top is massive limestone 2,500 to 3,000 feet thick, and the total thickness is 4,000 to 5,000 feet. The series is known as the Sinian and represents Cambrian and lower Ordovician of Europe and North America.

The strata are usually not mineral bearing, but the limestone is valuable for building stone, lime, and in some beds possibly as cement rock.

The massive limestone of the Sinian constitutes the base of the coal measures and is thus a key to their lower limit. At the contact with the coal measures it is cavernous and carries deep pits of pottery clay and some iron ore (limonite).

COAL MEASURES.

(Carboniferous.)

Deposited in apparent conformity on the eroded surface of the massive Sinian limestone are greenish, black, and brownish shales with ferruginous sandstones, iron ores, and beds of both bituminous coal and anthracite. These constitute the most important coal fields of China. The coal-bearing series is from 300 to 700 feet thick, and passes upward into heavy reddish sandstone. The number of coal beds varies from one to five or more and the thickness of individual beds from one to thirty-five feet.

OVER-COAL MEASURE SANDSTONES.

(Permo-Triassic.)

Above the Upper Carboniferous Coal Measures occur barren, red sandstones having a thickness of more than 3,000 feet. They are of no economic interest except in so far as they cover and more or less deeply bury the productive beds.

LATER COAL MEASURES.

(Triassic ? and Jurassic.)

In certain limited basins occur coal-bearing strata of sandstone and shale which are determined by plant fossils to be of Lower Jurassic age. West of Peking, apparently above the Carboniferous are others which von Richthofen assigns provisionally to the Triassic. With the exception of the last-named occurrence and the extensive Jurassic coal basin of Ta-tung-fu on the borders of Mongolia, these deposits are of limited local importance only.

IGNEOUS ROCKS.

(Carboniferous to Tertiary.)

In the provinces of Kiang-su, Shan-tung, Chi-li, and Liau-tung, igneous rocks of various kinds were erupted at intervals from late Carboniferous or Permian to the Tertiary. They are known to comprise granite, porphyry, andesite, rhyolite, basalt and tuffs, in part intruded into and across the strata, which are more or less metamorphosed thereby, and in part erupted at the surface as volcanics. It is possible that the post-Carboniferous granites of northwestern Chi-li are related to precious metal deposits, but the volcanics appear to have no economic significance.

ALLUVIAL GRAVELS AND LOESS.

(Quaternary.)

Heavy deposits of gravel and sand fill the deep valleys of the mountainous regions to depths from a few feet to two or three hundred. The history of this material is such that it is in part local stuff deposited near its source and in part foreign material which has been water-carried and sorted more than once in transportation from considerable distances. The surface has been worked for placer gold for centuries, but the Chinese have rarely been able to reach bed rock, where the principal accumulations probably occur.

A widespread deposit of northern China is the so-called loess, a yellow dust, composed largely of very fine siliceous sand with

alumina and iron, and also salts taken up from local underground waters. The loess is widely used for bricks; when mixed with pulverized limestone it forms a cement; and with the sands blown from the river beds it should be a valuable ingredient of concrete. These materials are so widely distributed as to be everywhere available.

NOTED OCCURRENCES OF ECONOMIC PRODUCTS.

GOLD AND OTHER METALS.

Metalliferous deposits (other than those of iron) are widely distributed in Shan-tung, Chi-li, and Manchuria.

Gold.—Hoover states[1] "Gold occurs at innumerable places throughout the whole of the mountainous portions of Chi-li, but only in a few isolated districts of Shantung. Some 50 districts were visited by the author and assistants."

Vein or Bed Rock Occurrences.—The same author says: "The gold quartz veins occur impartially through the older rocks, including the metamorphic limestone. There is no general direction or strike over the region, although individual districts are more or less parallel. Superficial decomposition is universally shallow, extending more often less than 20 feet than over 100 feet. There are two general classes of these veins: Normal fissure quartz veins, gash veins.

"The fissure veins are of two quite distinct types. First: narrow veins, which are composed of ore of bluish ribboned structure, showing a large proportion of lead sulphides, and usually of high grade. Second: wide veins of low-grade milky-white quartz showing almost exclusively iron sulphides, usually in large masses.

"Of the former, the main reef at Ching Ch'ang Kou Liang, lying 40 miles northwest of Chow Yang, in Chi-li, is a good example. Here the vein varies from 12 to 24 inches wide, continuing between well-defined walls; it has been driven upon continuously for over 4,000 feet in length, and is nowhere com-

[1] *Op. cit.*, p. 327.

pletely extinguished. It shows two ore chutes aggregating over 1,000 feet long; the one is a bluish ribboned quartz about 60 per cent. free milling, and contains about 10 per cent. sulphides of lead, iron, copper, and zinc. It has yielded by native methods, aided by foreign pumps, 43,000 ounces of gold from 39,000 tons in the last six years.

"So far as observed, all the deposits in Shantung are of the second type, and they also occur north of the Great Wall, but not of the same extreme size as in Shan-tung. The Chow Yuen mines in Shan-tung are a good example; here the vein crops out boldly for over a mile from 30 to 90 feet in width. The ore occurs in undetermined chutes of indeterminate size through the huge mass of quartz, which everywhere contains great vuggs of iron pyrites. The ore is about 40 per cent. free milling, shows 15 to 20 per cent. of pyrites, and the general average of ore is of low grade."

With reference to what is probably a typical ore deposit in the old rocks of Shan-tung, there is an account of a mine near Wei-hai-wei, which may be summarized in part as follows:[1]

The country rock is metamorphic gneiss which is traversed by veins of pegmatite, aplite, and quartz, and dykes of diorite. The pegmatites, which are in part coarse, are elsewhere represented by quartz veins with wolframite, tourmaline, magnetite, and other minerals. Next in genetic sequence are the aplite dykes, which are parallel in strike with the pegmatites but intersect them on the dip. The diorite dykes cut the others nearly at right angles. Auriferous quartz veins formed in the aplite dykes often along the main walls, but also as spurs and cross veins. In consequence of fracturing and secondary silicification the aplite and primary quartz were largely replaced by white secondary quartz forming an ore body over 20 feet wide with an average assay value for the full width of $9.

Metals other than Gold.—For precious metal deposits other than those of gold, the following from Hoover[2] may be considered authoritative:

[1] "Gold mining near Wei-hai-wei," by W. D. Verschoyle, *Eng. and Mining Jour.*, November 17, 1906, p. 919.

[2] *Op. cit.*, p. 329.

"No silver deposits of any consequence have been found in Shan-tung, but some mines have been worked to a considerable extent in Chi-li, particularly near Ch'öng-tö (Je-hol). The principal mines have been worked by foreign methods, and consist of a series of quartz veins in limestone. These veins carry throughout well-distributed argentiferous galena in small quantities, but more particularly lenticular masses or seams up to one foot wide and 100 to 200 feet long of almost solid galena, yielding up to 500 ounces of silver to the ton. Silver occurs native, as sulphide, chloride, and as ruby silver, and is associated with the sulphides of lead, zinc, arsenic, and antimony. There is no gold traceable.

"The rich ore bodies are very erratic, and failure resulted from the installation of foreign methods, although the natives, by continuing the use of pumps, are working 850 feet deep at Ku Shan Tzu. Other small silver-lead veins were observed associated with felsite dykes, but were also very narrow."

In regard to Manchuria the following statement is made by the Geological Survey of Japan.[3]

"Gold is often contained in quartz veins, traversing gneiss, quartzite, clayslate, granite or contact zone of gneiss and granite, etc.; but these veins are generally thin and barren of gold. The greater part or almost all the gold is washed from sands or pebbles of Quaternary deposits, as placers. Though localities of placer gold are abundantly known yet they are scarcely worth mentioning here."

The oriental habit of depreciation, which is so apparent in this paragraph, may be justified by many of these veins and placers, but some of them will probably be profitably worked nevertheless.[4]

Placers.—The concentration of gold and other heavy minerals in placer deposits obviously depends on the richness of the original sources and less obviously but no less directly upon the amount of original gold-bearing rock concentrated and the num-

[3] *Bulletin of the Imperial Geological Survey of Japan*, Vol. XVIII., No. 2, Tokyo, 1905, p. 11.

[4] See Hosie, *op. cit.*

ber of sortings to which it has been subjected. The richness of the source is commonly a local fact, but where gold is widely distributed, as in Chi-li, it may not be the most important one. The volume of rock disintegrated and the degree of concentration attained depend upon the history of erosion throughout the whole region. Brooks,[1] whose views have resulted from studies of placers in general and those of Alaska in particular, first called the writer's attention to the fact that rich placers occur in countries where the rocks had suffered deep decay because the surface had been low and flat, and where the decayed rock had subsequently been eroded and washed one or more times in consequence of one or more uplifts. Such is the history of the Yukon district, which has been discussed with reference to repeated concentration by Smyth[2] in a general article on the relation of placers to the history of the surface or physiography. Such is also the history of North China.

During a long period (covering Cretaceous and early Tertiary time) Asia was a comparatively low continent. The great heights have developed since then. While low the surface rocks became deeply decayed.[3] When elevated the decayed rock was eroded and distributed by winds and streams; and when re-elevated still further distributed, sorted, and concentrated. At least four stages of physiographic development have been distinguished in North China[4] and some of the older gravels have undergone transportation and sorting two or three times. Other accumulations are recently derived and in the first stage of concentration. A study of the history of streams and their deposits coupled with a survey of the distribution of auriferous veins should lead to a selection of localities where rich placers may exist. In this connection the yield of superficial gravels, long worked by the Chinese, would have a certain bearing, but it is

[1] "Placers of the Seward Peninsula," by A. H. Brooks, U. S. Geol. Survey, Bull. 328, 1907.

[2] "Origin and Classification of Placers," by H. L. Smyth, *Eng. and Min. Jour.*, Vol. LXXIX., 1905, pp. 1045, 1179 and 1228.

[3] "Relations of Secular Rock Disintegration," R. Pumpelly, *Am. Jour. Sci. and Arts*, Vol. XVII., February, 1879. "Research in China," Vol. I., part 1, p. 245, Bailey Willis, Carnegie Inst. publication, No. 54, 1907.

[4] B. Willis, *op. c't.*, p. 261.

from the deeper beds and on bed-rock that the greater returns are to be expected.

Hoover says:[5] "The streams through the mountains of Chi-li all contain some gold, and many do so in Shantung. Such deposits through the mountain ranges have been the main sources of China's gold product for centuries, and, even at the present time they are constantly being washed in the neighborhood of the richer quartz districts, wherever the natives can earn a few copper cash per day.

As previously noted, the structural changes of the range have made these deposits secondary, while the primary deposits—the gold on the bottom bed-rock—except in one instance within this region, have probably never been touched.

The filled cañons or valleys are always the course of a considerable stream, and any attempts of the Chinese to reach the real bed-rock, which they reasonably conceive to be very rich, have been foiled by lack of means to overcome the water. The tunnel at Ching Ch'ang Kou Liang drains such a buried basin and stream bed for about three-quarters of a mile, and has yielded enormous returns of gold. Here the bed-rock is covered by 80 to 100 feet of gravel and sand, containing a small amount of gold from the top down, but particularly concentrated on the bed-rock."

Gold in Manchuria.—In regard to the occurrence of gold in Manchuria, the following may be quoted from Hosie:[6] "The minerals of Manchuria have not yet been scientifically explored, but gold, iron, coal, and soda are extensively worked, and silver, copper, and lead are known to exist. Gold is widely distributed throughout the three provinces of Manchuria; but the richest deposits are found in the far north, on the right bank of the Amur, the dividing line of Manchuria and Siberia. . . . In Fêng-t'ien gold is known to exist at two places in the Liao-tung peninsula, in the east near the city of T'ung-hua-Hsien, and a few miles to the north of Mao-êrh-shan, between the Ya-lu River

[5] *Op. cit.*, p. 328.

[6] "Manchuria, its People, Resources, and Recent History," by Alexander Hosie, Methuen & Co., London, 1901, pp. 212–214.

and the Ch'ang-pai-shan mountains. In Kirin it is found forty miles to the northeast of Hun-ch'un, near the Russian frontier, in the bed of a tributary of the Tumên, still further north in the valley of the Sui-fên River, which flows into the Amur Bay on which Vladivostok stands, sixty-five miles west by north of Hun-ch'un in another tributary of the Tumên, on the banks of the Upper Sungari and its tributaries, and seventy miles to the east of Sansing—a town at the junction of the Sungari and the Hurka or Mu-tan River—near the head waters of a river which flows into the Sungari to the north of that town. In the Hei-lung-chiang province I noticed between the mouth of the Sungari and Blagoveschensk, and on the right bank of the Amur, the gold-mining camps of T'ai-p'ing-k'ou, between the Russian villages of Hingan and Pompeevka on the opposite bank, and at Kuan-yin-shan, opposite Raddevka. There is another Chinese mining camp fifteen miles northwest of Blagoveschensk, and forty miles east of the junction of the Shilka and Argun is Mo-ho, the most important mining camp in Manchuria, on the right bank of the Amur, about a mile above the Russian village of Ignashina or Ignatina. The mines themselves lie twenty-three miles inland. Here rich deposits of gold are found in the bed of a small tributary of the river which joins the Amur below Albazin. . . . Gold is also washed in the beds of the Arakan, which joins the Argun thirty-five miles southwest of its confluence with the Shilka, and the Urgi, a tributary of the Kang, which enters the Argun between Staro- and Novo-Tsuruhaitu. Gold is no doubt found in other parts of Manchuria, but the above are the best known centers."

COAL.

The coal resources of North China and particularly of Shan-si were estimated by von Richthofen as extraordinary in quality, quantity, and accessibility, and the impression thus created still prevails, so that China is looked upon as having a reserve upon which other countries may draw when the coal reserves of Europe and America shall run low. Richthofen's work was a reconnaissance and his estimate an excessive one. The notion that

China has coal to spare takes no account of her own needs, present and future, which are now sufficient to occasion exploitation of all the fields to the depth permitted by Chinese methods, and which when China develops her industries will tax the productive capacity of her possible mines. It would be well for the people in the third and fourth generations that the statesmen should early take measures looking to the most conservative exploitation of the coal fields consistent with the growth of manufactures rather than the cheapest production.

A summary account of the best known fields follows, the data being drawn from von Richthofen,[1] Drake[2] and other sources, as noted.

Shan-tung.

Shan-tung possesses a number of small coal fields of limited extent, each one being a remnant of the once widespread coal-bearing strata, which are preserved in basins or on downthrown fault blocks. They are of great importance to the province as they are somewhat widely distributed within it and are sufficient to supply its needs for a considerable period, but they are too small to figure largely in the assets of the empire.

The coal field of *I-chau-fu,* Shan-tung, lies in the alluvial plain 12 miles southwest of the city of that name (long. 118°. lat. 35°). The strata dip 15° to 30° easterly. There is one bed three to five feet thick with a limestone foot-wall and probably others lower as well as higher in the sequence. The outcrop and surface workings extend to a considerable distance toward the west and south. The coal is pure and bright bituminous, and is mined as lump and fine coal. The latter is coked.[3]

The coal field of *Po-shan* (long. 118°, lat. 36° 30′) lies near the northern margin of the mountains and is reached by a branch line of the German-built railway that traverses the province from east to west. It is probably the largest field in Shan-

[1] "China," Vol. II., Uebersicht der nordchinesischen Kohlenfelder, Chap. xiv., pp. 783–792, and special descriptions throughout the volume, by Ferd. v. Richthofen, 1882.

[2] "The Coal Fields of Northeastern China," by Noah F. Drake, *Am. Inst. M. E., Trans.,* Vol. 31, 1901, pp. 492–512.

[3] Von Richthofen, *op. cit.,* pp. 184–186.

tung. Richthofen estimated its area at 12 German (250 English) square miles. He observed workings on one bed reported to be six to eight feet thick, but a complete section of the measures was not obtained. The coal is bituminous of excellent quality.

At Fang-Tzi south of Wei-hien (long. 119°, lat. 36° 45′) a colliery has been opened under German direction on old Chinese workings. The shaft penetrates sandstones, which carry poor Jurassic coal seams, to two Carboniferous coal beds, one three to four meters, the other four meters thick.[1] The Carboniferous rests on granite, an unusual relation as the massive Ordovician limestone is immediately below the coal measures in all other known occurrences.

Von Richthofen enumerates altogether seven coal fields in Shan-tung.[2] The Jurassic deposits are of little consequence. The Carboniferous fields occur in all but the one instance not far above the conspicuous limestone and in beds practically parallel with it. The extension of the coal beds under cover may therefore be traced by the limestone and the occurrence of coal measures which do not outcrop may be inferred in some situations where the limestone dips beneath the plain. Proper stratigraphic studies at such localities may serve to direct successful boring operations and add to the known fields. The conditions are apparently favorable near Tsi-nan-fu.[3]

Chi-li.

The coal fields of the province of Chi-li have been described by Pumpelly, von Richthofen, and Drake from original observations. For the single well developed *Kaiping* field, Hoover's[4] account contains many interesting details of history and technology, but Drake's descriptions are the most recent and complete for all the fields.[5]

[1] "Beitrage zur Geologie von Ostasien," by Th. Lorenz, *Deutsche Geol. Gesell.*, Vol. LVII., 1905, p. 475.

[2] *Op. cit.*, p. 785.

[3] "Research in China," Vol. I., p. 81, 1907, by Willis and Blackwelder, Carnegie Institute of Washington.

[4] "The Kaiping Coal Mines and Coalfield, Chi-li Province, North China," by C. H. Hoover, *Eng. and Min. Jour.*, August, 1902.

[5] Drake, *op. cit.*

The Kaiping field, with mines at Tong-shan, Lin-si, and Si-shan, lies 100 miles east of Peking in the alluvial plain bordering the Gulf of Chi-li. It is traversed by the trunk line from Manchuria to Tientsin and has been worked by European methods since 1879. As mapped by Drake the field is about 18 miles long and from one to possibly three miles wide. Twelve to thirteen coal seams are distinguished and the aggregate thickness of those over two feet is from 60 to 96 feet in different parts of the area. The beds lie in a synclinal basin, dipping 30 to 90 degrees and outcrop occasionally through the alluvium along the northwestern side at the foot of limestone hills. The southeastern margin is entirely buried. At its northeastern end the basin is simple, but toward the southwest, at Tong-shan, it is involved in sharp keel-shaped folds or faults. The coal is classified as "Navy," "Locomotive" and "Household" and Hoover gives the following average analyses:

	Navy.	Locomotive.	Household.
Coke.	71.06	67.20	64.15
Volatile.	21.78	20.45	19.35
Moisture.	0.64	0.68	0.61
Sulphur.	0.98	1.16	0.95
Ash.	5.54	10.52	15.23
	100.00	100.01	100.29
Spec. grav.	1.285	1.32	1.32

West of Peking, about 14 miles from the city, the Western Hills rise abruptly from the plain and are traversed by the deep valley and canyon of the Hun-ho. The heights consist chiefly of the Sinian limestone and overlying Carboniferous. This is the Wang-p'ing field, of which Drake says: "The region, as a whole, is one of severe folding so that the strata often stand on edge, show a crushed condition, and are broken by numerous small faults."[1] About 260 feet above the Sinian limestone is one large coal bed 35 feet thick. It is the principal one of several contained in a sandstone formation about 300 feet thick, to which von Richthofen gave the name of the Liu-li beds. Above the Liu-li beds von Richthofen enumerates:[2] Unproductive

[1] *Op. cit.*, p. 501.

[2] "Letters to the Shang-hai Chamber of Commerce," p. 6, 1872.

strata 1,500 feet; black slate 500 feet; "Tai-ngan" series 1,400 feet, with 13 coal beds from a few inches to 10 feet thick; sandstone 1,000 feet; "Miau-ngan" series containing two coal beds said to be six or seven feet thick; variegated shales and sandstones 2,000 feet; "Ta-tsau" series consisting of several beds of anthracite in yellow and black argillite, 600 feet; and at the top the "Fu-tau" series of gray sandstones and argillites with four coal seams that vary from a streak to nine feet in thickness.

This extraordinary series, 7,000 or 8,000 feet thick and comprising three sets of anthracite beds and one bituminous productive measure, is known only in this area west of Peking, where the strata are much disturbed and are also intruded by porphyries. If we compare it with sections in adjacent regions we can only correlate the strata above the "Liu-li" formation with the Permo-Carboniferous sandstones, which are elsewhere commonly barren. It is also possible that there are repetitions due to complex structures not recognized in the reconnaissance surveys to which thus far we owe what we know. Drake contributes a map and many details concerning that portion of the field nearest Peking.[1]

Fifty miles west of Pau-ting-fu, Chi-li, a very small coal basin known as the *Ling-shan* (or Ning-shan) field is preserved by downfaulting of a synclinal fold among the ancient gneisses. It is a typical example of the small fields which occur here and there among the ranges and which have only local significance.[2]

Shan-si.

The great anthracite field of southern Shan-si, which lies between longitude 112° and 114° and stretches from latitude 35° 30′ to 38° 30′ has been described as the *"P'ing-ting"* field from a part of its northern area and as the *"Tze-chou"* field from a southern locality. When well known, no doubt several basins will be distinguished. No map of this field as a whole yet replaces that published by von Richthofen,[3] although his reconnaissance has been repeated and supplemented by a number of

[1] *Op. cit.*, p. 498.

[2] See Drake, *op. cit.*, p. 508, and also "Research in China," by Bailey Willis and Eliot Blackwelder, Vol. I., part 1, pp. 148 and 153, and atlas, 1907.

[3] China—Atlas Tai-yuen-fu and P'ing-yang-fu sheets.

mining engineers. Drake has published a special article on the Tze-chou district, which gives more reliable local details, as it is based on actual mapping.[1]

The area of this coal field of south Shan-si was conservatively estimated by von Richthofen at 10,150 square geographical miles (34,870 square kilometers, 13,400 English square miles). This takes no account of what may be called the eastern fringe of the field (a wide belt in which the strata are more or less folded or faulted) but comprises only the central and western part, which von Richthofen believed to be undisturbed and throughout which the beds are supposed to have but a gentle dip. While it is doubtful if the wide extent of flat beds exists, for folds and faults strike into the unexplored area from adjacent districts, it is probable that the whole field has at least the productive area which von Richthofen assigned it, say 13,500 English square miles.

The productive coal measures consist of 300 to 700 feet of sandstone and shale with one principal coal bed and several subsidiary ones. In regard to the district about Tze-chou, Drake says:[2] "The average thickness of the main coal bed is probably not less than 22 or 23 feet . . . In the coal mines about 2½ miles northeast of Tze-chou rooms are opened which expose the bed from top to bottom. In two rather widely separated places in one of these mines the coal measured 17 and 22 feet respectively. . . . In another mine the bed is quite regularly divided as follows:

"Good firm coal"	6 feet	
"Shale, carbonaceous"		1 inch
"Hard firm evenly good coal"	14 feet	
"Earthy friable coal"	3 feet	
	23 feet	

In regard to other parts of the field we have not equally definite data, but a thick seam appears to occur widely. Kurita says:[3] "During the months of October, November, and Decem-

[1] "The Coal fields around Tse-Chou, Shan-si," by N. F. Drake, *Trans. Am. Inst. M. E.*, Vol. 31, 1901, p. 261.

[2] *Op. cit.*, p. 271.

[3] *Eng. and Min. Jour.*, Vol. LXV., 1898, p. 491. "Coal and Iron Deposits of Eastern China," by Andrel Kurita.

ber of 1896 and 1897 the writer made an examination of much of this province, his work extending over an area of more than 200 miles north and south and 30 miles east and west, Tse-chou to Yu. This whole area is one unbroken coal field with workable coal from 25 to 50 feet in thickness. This statement is not the result of deductions from surface indications, but from an examination of actual mines as worked by the Chinese."

The maximum figure, 50 feet, is not equaled by other observations. It may represent a portion of the bed thickened in consequence of disturbance.

Von Richthofen estimated the total thickness of workable anthracite in all the beds, throughout the 13,500 square miles, at 40 feet. Drake gives 22 feet as a more probable average. If there were 40 feet there would be as von Richthofen calculates 630,000,000,000 tons of coal. If, as is probable, Drake's estimate is nearer the truth, there are approximately 350,000,000,000 tons of 2,000 pounds.

The Shan-si field produces a high grade anthracite in which, according to seven analyses cited by Drake,[1] the fixed carbon varies from 80 to 87 per cent., the volatile from 2 to 3.5, the water from 1.5 to 3.5, and the ash from 6.5 to 14.

The field lies in a deeply eroded upland, at an elevation of 2,000 to 5,000 feet. It is directly tributary to the populous plains on the east and south of it and to the rich interior basins of T'ai-yuan-fu, Ping-yang-fu, and the Wei valley. It has for North China much the same significance that the Appalachian field has for the eastern United States. The first operations toward extensive development are even now being undertaken by the Pekin Syndicate at P'ing-ting-chou in the northern part of the field in consequence of the completion of the railroad from Shön-tö to T'ai-yuan.

Shan-si also possesses other coal fields, situated in the western and northwestern parts of the province.

Between the Huang-ho and the Fön-ho, where they flow from north to south, lies an elevated region, regarded by von Richthofen as a plateau and probably like that of eastern Shan-si more

[1] *Op. cit.*, p. 273.

properly described as a broad low mountain belt. Though in wide basins but slightly inclined the strata are disturbed by folds on which the dip may rise to the vertical and which strike about north 30° east-south 30° west through the area. The surface is deeply eroded and the relief is both bold and high. The coal-bearing region is roughly 40 miles wide east and west and 100 miles long north and south, and it is probable that coal fields occupy one-half of it, 2,000 square miles, or more. The first account of the fields, which lie remote from highways, is that given by von Richthofen[1] who visited one locality in the eastern margin west of Ping-yang-fu. From that city he crossed the valley of the Fön-ho, which corresponds to a "graben" or downthrown fault block, and ascended the O-shan ("Ngo-shan"), a range of 2,000 to 3,000 feet high, rising abruptly by a fault-scarp. Coal measures occur in the valley at the base of the scarp. The scarp-face consists of the pre-Carboniferous (Sinian) limestone, and the heights above it repeat the overlying coal measures. Von Richthofen gives a section of 230 feet of sandstone and shale containing seven streaks or beds of coal from one inch to several feet thick, of which the highest was extensively worked. The mountain district west of the point to which von Richthofen penetrated is described as one crossed only by rough trails and without shelter for travelers. None has ever traversed it.

Le Prince-Ringuet, a French engineer of mines, who made an examination of certain parts of China in the interest of the Crédit Lyonnais, 1898–1899, made an excursion from Fön-chou-fu southwest into the mountains about 75 to 100 miles north of the point reached by von Richthofen. He says:[2] "An excursion southwest from Fön-chou-fu enabled us to fix the stratigraphy of this basin. In ascending the valley of the Siau-ho on the road to Si-chou one follows at first the beds above the Carboniferous which with some slight disturbances dip gently toward the northeast. . . . Traversing the series one reaches the coal measures at an altitude of 900 meters (Su-kou), the

[1] "China," Vol. II., p. —.

[2] "Étude géologique sur le nord de la Chine," by Le Prince-Ringuet, *Ann. de Mine*, 9th Ser., Memoires, Vol. 19, 1901, p. 393.

altitude of Fön-chou-fu being taken at 750 meters. One then passes through the Carboniferous limestone.[1] On reaching the plateau one comes upon the coal again wherever it has not been eroded or is not covered by loess. . . . Up to this point we have followed approximately the strike of the structure of Shan-si and the strata are found to be very regular. If we now take a transverse direction, that of the northwest-southeast course of the Sin-shui-kou-ho and its affluents, we may observe in the Carboniferous limestone a series of slight undulations and faults in which there frequently occur deposits of iron ore (the region of T'ao-che and of T'ao-hua-kou). The coal appears to exist only in synclines which pitch towards the southwest. . . . The great faults which were seen further to the northeast do not occur in this region. The metamorphic rocks, however, form chains similar to and parallel to that of the Ho-shan, for we found pebbles of them in the rivers and we saw an elevated chain to the west of the furthest point which we reached in these plateaus. This inference is furthermore confirmed by the occurrence of mica schists at Yu-kou, and of granite at "Pa-k'o-t'ao-oua" in the district of Ki-shan-hien, to the north of that city, which is situated in the lower course of the Fön-ho."

The western region of Shan-si is touched by the great highway from T'ai-yuan-fu to Fön-chou-fu, about 30 miles southwest of the former city. A shallow syncline is cut across by the mountain face and coal-bearing strata are brought down below the level of the plain. The long axis of the basin trends north by east and on the northwest rises the range of the Shi-hia-shan, which is a prominent anticline of older rocks. The extent of this field is not known but it is an important one for local supply and may contain a very notable body of coal. For local descriptions see von Richthofen[2] and Willis.[3]

Still further north in Shan-si near Ning-wu-fu (long. 112° 30′, lat. 39°) there are several small coal basins[4] of which

[1] No doubt the pre-Carboniferous (Sinian) limestone.

[2] "China," Vol. II., p. 430.

[3] "Research in China," Vol. I., part 1, p. 172.

[4] "China," Vol. II., pp. 363 and 391. "Research in China," Vol. I., part 1, p. 217. Atlas, Geological Sheet B1.

nothing definite is known. They are the northern outliers of the folds which constitute the fields of the western half of the province.

The coal fields of western Shan-si yield excellent bituminous coal. Von Richthofen regarded them as equally extensive with the anthracite fields of eastern Shan-si. In both districts he estimated on a flat plateau structure of the coal-bearing strata, and accordingly overestimated the probable area of productive measures, which are more or less sharply folded and consequently eroded on the anticlines. His over-estimate is probably greater in western Shan-si than in the eastern fields of the province and the area of bituminous coal is probably less than that of anthracite. The thickness of workable coal in the western field is unknown, but as there are no reports of a very thick bed, such as that at Tze-chou, it is probable that none exists. Von Richthofen cites one seam as worked and two others as of possibly workable thickness. On these data we can only conclude that the total coal of western Shan-si is considerably less than that of eastern Shan-si, which in a preceding paragraph is roughly estimated at 350 billion tons.

Still north of Ning-wu-fu, within the borders of Mongolia, is the remote coal field of Ta-tung-fu (long. 113°, lat. 40°). Unlike the already described coals, which are Carboniferous, this is of Jurassic age. It lies in an isolated syncline which stretches northeast-southwest for about 60 miles and is perhaps 15 miles wide. Von Richthofen observed three workable beds in one locality, and in another one bed 20 feet or more thick. He describes the coal as black, of brilliant luster, hard, and not dirty. It does not coke or swell and looks like anthracite. The analysis shows: "coke 68.1, gas 31.8." [1]

Although situated on the northwestern side of the mountain barriers of Chi-li this field of Ta-tung-fu may become an important factor in coal production on the completion of the railroad from Peking to Kalgan, if connected with Kalgan by a branch. It is very fortunately situated with reference to possible lines of traffic in Mongolia.

[1] "China," Vol. II., table of analyses opposite p. 784.

Manchuria is geologically the continuation of Chi-li and Shantung and comprises coal fields belonging to the Carboniferous and Jurassic. The following account is taken from a bulletin of the Geological Survey of Japan:[1]

"The 'Wu-hu-tsui' coal field lies near the sea, at a distance of about 17 kilometers south of F'u-chou or about 15 kilometers west of P'u-lan-tién railway station. It occupies a narrow belt of five kilometers extending from southeast to northwest. Coal Measure contains three coal seams, among them only one with a thickness of two to ten feet being workable. The basin of the coal field corresponds to a syncline, where the future work may be expected. The coal belongs to anthracite and is very brittle, giving only 10 to 20 per cent. lump. The following is the analysis:

Volatile Matter.	Coke.	Ash.	Water.	S.
11.42	76.69	9.19	2.70	0.50

"The 'Pen-hsi-hu' coal field lies on the upper 'T'ai-tzu-ho' at a distance 10 kilometers east of Liao-yang, occupying an area of six kilometers in a east-west direction and one-third of a kilometer in a north-south direction. Both extremities of east and west are cut by faults. Along the fault at the eastern extremity we see a large intrusive dyke of melaphyre, while from the western fault starts 'Hsin-tung-kou' valley. The southern part is composed of upper sandstone series and the northern of limestone of the lower Carboniferous. The Coal Measure contains abundant coal seams, among which four with a thickness of over 3 feet may be workable. The coal belongs to caking semi-anthracite and is very brittle, giving only 10 per cent. lump. The following is the analysis:

	Volatile Matter.	Coke.	Ash.	Water.	S.
No. 1.....	16.64	69.23	13.12	1.01	0.70
No. 2.....	22.65	65.99	10.29	1.07	1.26
No. 3.....	25.70	62.96	10.55	0.79	0.57

"The Yen-t'ai coal field lies at a distance of 11 kilometers east of Yen-t'ai railway station where a branch line to the colliery

[1] *Op. cit.*, pp. 11–13.

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starts. It occupies an area of 1⅓ kilometers in an east-west direction and 5 kilometers in a north-south direction.

"Coal Measure forms a syncline, the axis of which generally runs from north to south. Though the inclination of the strata is somewhat steep at the outcrops, yet it becomes gradually low, approaching to a synclinal axis, until at last it attains nearly horizontal layers.

"Coal Measure may be divided into two groups, the lower and the upper. The lower contains 13 coal seams, of which three alone may be workable; while the upper contains only three coal seams, but one of them has a thickness of two to five feet. The upper group is found only at the northern coal field and is eroded at the southern. The coal belongs to semi-anthracite and is very brittle, giving only 20 to 30 per cent. lump. The following is the analysis:

	Volatile Matter.	Coke.	Ash.	Water.	S.
No. 1.....	14.00	75.74	9.46	0.80	0.53
No. 2.....	14.46	74.26	9.85	1.42	1.05
No. 3.....	14.19	74.94	9.94	0.90	0.41

"The Sai-ma-chi coal field (Jurassic) lies along the Pa-tao-ho at a distance of 75 kilometers northeast of Feng-huanh-ch'eng. The northern mountain range is formed of Ta-ku-shan quartzite and the south of the plain also of the same formation. Jurassic forms here a long belt of 18 kilometers between Ta-ku-shan series. Coal seams occur in alternating strata of sandstone and clayslate, which is the lower horizon of the system. Coal seams are five in number but both sides sometimes diminish into two or three, the others thinning away. The thickness is variable but generally thin, the thickest being 2.6 feet. The coal belongs to anthracite or semi-anthracite and is very brittle. The following is the analysis:"

	Volatile Matter.	Coke.	Ash.	Water.	S.
No. 1.....	21.89	69.27	7.58	1.26	0.58
No. 2.....	27.82	57.28	13.39	1.51	0.87
No. 3.....	27.04	54.86	16.69	1.41	0.95

Any statement of the total amount of coal in North China is a guess rather than an estimate under present conditions of knowledge, but to indicate the position of the fields among those of the world a guess may be made as follows:

	Billion Tons.
Coal fields of Shan-tung, say	10
Kai-p'ing coal field, Chi-li, say	2
Wang-p'ing (no estimate possible).	
Scattered small fields, say	3
Anthracite fields of eastern Shan-si, say	350
Ta-tung coal field of Shan-si, say	50
Ta-tung coal field of Shan-si	50
Total amount of coal in North China, say	605

This guess may be 100 billion tons out more or less.

In comparison with these figures we may place the total amount of coal in the Appalachian coal field of the eastern United States, estimated by Mr. M. R. Campbell, chief of the Mineral Fuel section of the U. S. Geological Survey, at 650 billion tons.[1]

IRON.

North China is credited with a large supply of valuable iron ores, but on very slender information. Von Richthofen observed in 1870–71 the production of iron at Lu-an ("Lu-ngan-fu") and Lo-ping,[2] both places being situated in the great anthracite field of Shan-si. Of the ores, which are interbedded in the coal measures, he states that they are dug chiefly from the extensive outcrops or obtained in shallow shafts. They consist of limonite and siderite, "Brauneisenstein und Spatheisenstein." They are smelted in crucibles, which are stacked in anthracite between walls of loess. After the fire has been started with a bellows it is allowed to burn out under natural draft.

Regarding the occurrence of ore near Tse-chóu (the Lu-an district of Richthofen), Drake says:[3]

"The iron-ore, included in Fig. 1, lies in the north half of the

[1] Manuscript note, courteously communicated to the writer, November, 1907.

[2] "China," Vol. II., pp. 412 and 436.

[3] "Coal-Fields around Tse-chóu," by N. F. Drake, *Am. Inst. M. E. Trans.*, Vol. XXX., 1900, p. 274. See also "Coal and Iron in Eastern China," by C. D. Jameson, *Eng. and Min. Jour.*, Vol. LXVI., 1898, p. 365.

field. The part that is now being worked for iron-ore is a strip one to two miles wide, on the west slope of the I-hou-shan anticline, from near I-hou-shan to the north boundary of the field. The ore is hematite, and occurs as scattered nodules in a sandy clay stratum, below the flint-bearing limestone bed. From cursory examinations of outcrops, the iron-ore-bearing stratum appears to be from two to three feet thick. The present mine-workings are limited to this narrow strip, because there the ore-bed lies at shallow depths, so that it may be mined by open pits; whereas, over other parts of the field deep shafts and long tunnels would be required. The limited amount of ore, however, will probably never justify extensive mining over the area where it lies deep below the surface. This district has long been one where iron-ores were smelted, as is shown by the large heaps of furnace slags at a great number of the villages."

It is possible that under cover these ores will prove to be ferruginous limestones, too poor to work, as is often the case with similar occurrences.

Coal measure ores occur in Shan-tung,[1] and probably generally throughout the coal-bearing districts.

The descriptions of these iron ores of the coal measures of Shan-si place them in the class of the carbonate and black band ores of the Coal Measures of the eastern United States, which at the time von Richthofen wrote were an important source of iron, but in the present condition of the industry are of value only as a reserve to be drawn upon when the great stores of rich ores shall be exhausted. The United States will be very poor in iron when that condition arrives and North China is poor in iron unless she has other resources than those of the iron ores in her coal fields.

Von Richthofen mentions an occurrence of magnetic ore and hematite near certain hills of coarse hypersthene-gabbro which rise from the alluvial plain north of Tsi-nan-fu, Shan-tung. Nothing is known of any body of ore.

Attention is called in a preceding paragraph to the possibility

[1] "Schan-tung and Kiau-chou," by F. von Richthofen, pp. 57, 61, 123, 125, 184, Berlin, 1898.

that the metamorphic Wu-t'ai series of northern Shan-si, which contains lean magnetic and jaspery ores, may enclose bodies of rich ore. The region should be carefully examined, and the wide areas of still older schists should be surveyed with a view to discovery of iron ores, which the Chinese may have overlooked. Extensive magnetic work is desirable. The territory in which iron may be found is large and there is a reasonable probability that it is not altogether without ores such as occur commonly in similar rocks elsewhere.

In Manchuria iron ores are worked only at Ti-siung-shan south of Ts'au-ho-ch'eng between Sai-ma-chi and Ts'au-ho-kou. The deposit occurs in the contact zone of Sinian formation and gabbro. Ores are magnetite.[1]

CLAYS.

North China probably possesses a variety of residual clays, derived from feldspathic rocks, which are abundant and often decayed. She has great quantities of alluvial and eolian deposits composed of very fine material (loess), which is, however, usually high in silica. With the coal measures occur fire-brick clays,[1] and also shales such as are widely used in the United States for making various clay products.

A special occurrence of material of peculiar quality is that of the black, red, and yellow pottery clays which are found wherever the base of the Carboniferous coal measures is exposed. They fill cavities in the underlying limestone and are extensively dug by the Chinese at Po-shan, Shan-tung, throughout the coal field of Shan-si, and elsewhere.[3] Iron ores also occur with the clays. There are none of the glacial clays, which in North America and Europe constitute a not unimportant class for brick manufacture.

GLASS MATERIALS.

The manufacture of glass is an art which survives in but two localities in North China, so far as available data show, and at

[1] *Bull. Imperial Geological Survey of Japan,* Vol. XVIII., No. 2, Tokyo, 1905, p. 11.

[2] Drake, "Coalfields near Tse-chóu," *op. cit.*

[3] "China," Vol. II., pp. 203, 411. "Research in China," Vol. I., part 1, pp. 48, 49.

these places only for the production of toys or bric-a-brac. There is no doubt a field for extensive development of the industry.

Von Richthofen[1] describes the growth and decline of glass-making at Po-shan-hién, Shan-tung, which is still carried on in private establishments according to methods and with mixtures which are in part secret. Except that a pure quartz sandstone of the coal measures is employed, he obtained no information as to the materials, nor did the writer on visiting the houses of the glass-makers in 1903.

In the province of Shan-si, at a small village called Tau-ts'un, situated in the plain between Tai-yüan and Wön-shui-hién, glass articles similar to those made at Po-shan are produced by the members of one family in the premises of several houses. The materials are sandstone, feldspathic rock containing large crystals of violet-blue fluorite and galena, and a colorless crystalline salt, mixed in the proportions of 20, 7, and 26 parts, respectively. The feldspathic rock is said to be obtained from a vein in granite 90 li (25 or 30 miles) west of Fön-chou-fu. The sandstone is from a bed above the coal measures in the vicinity. The salt was reported as being made from pyrite, but is more probably one of the impure soda-potash salts of the salt lake basins of the province. Raw glass is made by melting a charge of these ingredients of about 75 pounds weight in a crucible in a furnace without a chimney or bellows, at a moderate heat. The raw glass is remelted, colored, and worked into small bulbs, flasks, rings, buttons, and beads.

In these interesting survivals of the industry there is perhaps the promise of a future development of glass manufacture, to meet the need for window glass, for which paper is now substituted, and for glass in its many useful forms.

II. MIDDLE YANG-TZĬ REGION.

The district which may be described as the Middle Yang-tzĭ Region lies on both sides of the middle course of that great river between the cities of Chung-K'ing in Ssĭ-ch'uan and Kiu-kiang

[1] *Op. cit.*, Vol. II., p. 202. Also "Schan-tung and Kiau-chou," F. von Richthofen, 1898, p. 185.

in Kiang-si. It embraces the section of the river between I-ch'ang and Kiu-kiang with the Poyang and Tung-t'ing lakes, the heart of China from the commercial point of view; the hill region south of the Yang-tzï nearly to the headwaters of the navigable tributaries of that great artery; and in contrast to these districts it includes also the high mountains of central China west of I-ch'ang, which are shut off by their ruggedness, though traversed by the Yang-tzï in its world-famous gorges.

Of political provinces the region comprises all or parts of An-hui, Ho-nan, Hu-peï, Ssï-ch'uan, K'ui-chóu, Hu-nan, and Kiang-si.

Geologically this region resembles North China in the non-metamorphic condition of the Paleozoic and younger rocks. There is a basement of old schists, which is exposed in many places, but the prevailing hard rocks are limestones of different ages interbedded with some shales, sandstones, and coal beds.

The adjoining geologic provinces on the north and south are characterized by igneous activity and as the boundaries are irregular and known vaguely at widely separated points only, intrusives and local contact metamorphism probably occur within the area here described as generally non-metamorphic.

The type section of geologic formations is exposed in the I-ch'ang gorge between the village of Nan-t'ou and the city of I-ch'ang in the western part of the province of Hu-peï. At the base near Nan-t'ou are granite and gneiss (pre-Cambrian). The superjacent stratigraphic sequence consists of limestone, 4,500 feet (Sinian, *i. e.*, Cambro-Ordovician); shale, 1,800 feet (middle Paleozoic); limestone, 4,000 feet (upper Carboniferous); and red beds (early Mesozoic). The strata are apparently conformable, but closer study will probably show an unconformity beneath the red beds.[1]

The pre-Cambrian gneiss, schist, and granite occur extensively in the low hill country north and northeast of Hankow, and in an isolated area west of I-ch'ang, between the I-ch'ang, and

[1] For detailed description and geologic maps see "Research in China," by B. Willis and E. Blackwelder, Vol. I., pp. 267 to 296 and Atlas. Carnegie Inst. of Washington, publication No. 54, 1907.

Lu-kan gorges of the Yang-tzï. Their distribution south of the river is not well known, but as the basement of a disturbed and deeply eroded sedimentary series they may appear anywhere.

Mica-schists and gneiss traversed by dykes of aplite are the rocks described northeast of Hankow[1] and they probably have a wide distribution. Granite-gneiss constitutes the mass exposed on the Yang-tzï above I-ch'ang. Pre-Cambrian slate, a somewhat altered calcareous sediment, occurs as boulders in an ancient glacial formation beneath the Sinian limestone at Nan-tou, but is not known in place.

It is probable that these old rocks are locally metalliferous, but no deposits of any value are described in available literature. A consular report cites occurrences of agate, antimony, barytes, coal, copper, gold, iron ore, lead, mercury, and silver,[2] the principal localities mentioned for the precious metals being "Chang-lo" and "Ho-feng-chow" on the Hunan border, 150 miles southwest of I-ch'ang. The meager information available from this source implies that the metals are not produced in any considerable quantity.

Coal, which is more important at Hankow, the central knot of commercial lines, than any other mineral, is said to be abundant throughout the tributary region and is certainly widely distributed. There is, however, nothing definite in print on which to form a judgment of its adequate abundance considering the demands likely to develop for manufacturing and transportation. The following are some of the available statements:

"It would be more difficult to name hills in this consular district where coal does not exist than where it does."[3]

Kingsmill refers to many localities near the Yang-tzï which he had visited or from which he had reports.[4] The references

[1] "Études geol. sur le nord de la Chine," by F. Leprince Ringuet, *Ann. des Mines*, 9th ser., Memoirs, Vol. 19, 1901, p. 411.

[2] Report for the Consular District of I-ch'ang, by C. T. Gardner, British Consul, *Jour. China Branch, Roy. Asiatic Soc.* for 1884, Shang-hai, 1885.

[3] C. T. Gardner, British Consul at I-Ch'ang, *op. cit.*

[4] "Notes on the Geology of China," with more especial reference to the Provinces of the Lower Yang-tse; by T. W. Kingsmill, *Jour. North China Branch of the Royal Asiatic Soc.*, p. 119, 1868.

are too numerous and too difficult to locate to be cited in full without detailed maps, but we may note that he distinguishes two horizons at which coal beds occur; one, the "lower coal and iron shales," 600 to 800 feet thick, being near the middle of his "Tung-t'ing" series and dividing the great Carboniferous limestone in two; the other, the upper member of his "Chung-shan" series, being higher up in the geologic column and in all probability of the same age as the early Jurassic (Rhetic) coals of the middle Yang-tzï. Throughout southern Kiang-su, An-hui, Kiang-si, and Hu-nan these strata are thrown into folds, which have a northeast-southwest trend and are deeply eroded. The Carboniferous or Jurassic coals survive in more or less extensive basins.

Von Richthofen's comments on Kingsmill's observations, communicated in a letter to Whitney, confirm the impression that the coals along the lower Yang-tzï and its tributaries are generally thin and high in ash.[1] He says that the deposits compare unfavorably with those of North China,[2] but remarks on the district of Lo-p'ing, west of the Po-yang lake as one which possesses valuable bituminous coal in notable quantity and good position. Elsewhere[3] he says: "Near Poyang lake, the edges of the 'King-te-chin' schists are overlain by coal-bearing strata, which are almost undisturbed. The locality (Lo-p'ing) is the first in China which has become of practical value to foreign enterprise; it supplies the greater portion of the coal used by the American steamers on the Yang-tsï."

The coal fields of southeastern Hu-nan and southern Kiang-si are apparently far more important than any nearer the Yang-tzï. In the article to the *K. K. Gesellschaft* at Vienna, von Richthofen says:[4] "I visited the coal fields of Hu-nan in 1870 and found indeed that they occupy a considerable part of the province, probably not less than a third of its area. The Siang River and its many navigable tributaries flow from their sources to the city of

[1] *Am. Acad. Arts and Sci., Proc.*, Vol. VIII., 1868–73, p. 116.
[2] "Die Kohlenfelder Chinas," by F. von Richthofen, *Kais. konigl. Gesell. in Wien, Mittheilungen*, Vol. XVII., 1874, p. 117.
[3] *Am. Jour. Sci.*, 3d ser., Vol. I., p. 181.
[4] *Op. cit.*, p. 175.

Siang-tan almost wholly in a small but uninterrupted coal-bearing district, which carries anthracite in the south and bituminous coal in the northern portion."

Parsons states:[2] "The southern half of the province is one vast coal field, both anthracite and bituminous. . . . The geological structure of the country is much disturbed, the stratification having a dip of 30° to 45° in some localities. This disturbance has resulted in so breaking up the coal deposits as to render them soft and friable. In other localities, however, the disturbance has had less serious force and coals are found of a hard, firm texture, some of the anthracites being sufficiently hard and of such chemical composition as to permit of their use in blast furnaces."

Reference to recent developments under foreign direction at Yü-kan-hién south of the Po-yang lake, and at P'ing-siang in the west of Kiang-si near Yuan-chóu is made in a British consular report, but without details.[1] The latter place is connected by rail with Li-ling in Hu-nan, and the road was to be extended to navigation on the Siang (Hsiang) river to supply the Hanyang iron works with coal and coke.

The occurrences thus far cited are found in the hill region east and south of Hankow. In the western part of the middle Yang-tzï region up the river from that city there are two coal fields worthy of note. The more accessible of these is the well-known Kui-chóu basin which is traversed by the Yang-tzï forty to sixty miles above I-ch'ang. Six coal beds are worked in the bluffs along the river. The coal is of early Jurassic (Rhetic) age and is described as an inferior friable anthracite.[3] The basin is the most eastern occurrence of the coals which are widely distributed throughout Ssï-ch'uan and are said to be of much better quality higher up the river.

[1] "Hu-nan, the Closed Province of China," by W. B. Parsons, *Nat. Geogr. Smithsonian Inst. Contributions to Knowledge*, 202, 1866, p. 6.

[2] Report respecting the Province of Kiang-si, by W. J. Clennell, consul at Kiu-kiang, Great Britain, House of Commons, Sessional Papers, Vol. LXXXVII., 1903, p. 35.

[3] "Geol. Researches in China, Mongolia and Japan," by Raphael Pumpelly, *Mag.*, Vol. XI., p. 398, 1900.

A much less accessible and probably less extensive field is that of T'an-mu-shu-p'ing, a village on the Ta-ning river which enters the Yang-tzï from the north at Wu-shan-hién above the gorges. The Carboniferous limestone there lies in a broad flat syncline and carries a bed of anthracite something over three feet thick which is cut through by the canyon and therefore completely drained. The basin is 3½ miles across. Its extent along the strike is unknown. The coal is shipped in small boats down the rapid river, which flows through stupendous gorges that forbid any other mode of transportation.[1]

Iron ore is said to be widely distributed throughout the provinces east and south of Hankow. It occurs as limonite, hematite, and magnetite, the latter being results of local metamorphism probably. Kingsmill quotes as follows from Markham, the British consul at Chin-kiang on the Yang-tzï.[2]

" Near Chin-kiang itself, at a place called ' Lui-shan,' five miles distant, and also at another spot near ' Kaotsêh-chên,' some fourteen miles away, the chert-bearing limestone seems to occur; the succeeding shales are ferriferous. At ' Lui-shan,' in some detached hills, apparently belonging to this portion of the series, I collected some fine specimens of hematite; the beds cross the hill with a dip of about 60° towards the north; they seemed to be about 30 feet in thickness, as, although not exposed for that distance, the surface was covered with particles of the ore. Simple quarrying is here all that is necessary to obtain the metal. Close by, within about 150 feet, the band of cherty limestone, about 200 feet in thickness, likewise was found lying conformably with the iron beds. This hill is about 200 feet in height, and within a mile of a navigable canal leading to the river Yang-tzï; some specimens of the ore here were highly magnetic. Though I did not succeed in finding at this locality the coal-bed spoken of above, I have little doubt of its existence. The other locality is within two miles of a tile- and pottery-village called

[1] See map and detailed section, geologic atlas sheet d6, " Atlas of Research in China," by B. Willis, E. Blackwelder and R. H. Sargent, also general description, *ibid.*, Vol. I., pp. 278 and 291.

[2] " Notes on the Geology of China," by T. W. Kingsmill, Corr. Sec. North China Branch of the Royal Asiatic Soc., 1868, p. 127.

'Pao-kiang-yau,' itself about three miles from 'Kaotsêh-chên,' a village situated on the main road to Nanking, with which, as well as 'Chinkiang,' it has likewise water communication. Here also the ore is accompanied by limestone; but, owing to the intrusion of a large mass of porphyry, both iron and limestone are metamorphosed, the former into magnetic ore, the latter into white crystalline marble, much used by the natives for the manufacture of whiting.

"I also noticed beds of iron ore at the foot of the 'Chung-shan,' within three miles of the Taiping gate of Nanking; they were visible here at the head of a small valley which cut into the rocks underlying the 'Chung-shan' series. My specimens collected here, however, were by no means equal to the others; but, owing to their position, a good section could not be obtained of the beds."

In 1900 Vogelsang made a journey northward and westward from I-ch'ang through western Hu-pei in search of reported copper ores. He found traces, but no body of ore, and although he carried out a route survey he unfortunately gives no intelligible account of the geology.[1]

(To be continued.)

[1] "Eine Reise durch das Gebirgsland des Ta-pa-shan," Dr. K. Vogelsang, *Petermanns Mitt.*, Band 50, 1904.

GEOLOGY OF THE CEMENT BELT, IN LEHIGH AND NORTHAMPTON COUNTIES, PA., WITH BRIEF HISTORY OF THE ORIGIN AND GROWTH OF THE INDUSTRY AND A DESCRIPTION OF THE METHODS OF MANUFACTURE.

FREDERICK B. PECK.

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I. INTRODUCTION.

A quarter of a century ago, the greatest asset of the Lehigh Valley was its iron industries. At that time this region was

perhaps the most important iron manufacturing section of the United States. But the discovery of the tremendous bodies of ore in the Minnesota and Michigan fields, brought about the westward march of the center of iron production, so that to-day in passing up the valley one notes the comparative inactivity of the iron trade, with here and there an idle or dismantled furnace. Now the smoke from the furnaces and coke ovens of the Monongahela Valley darken almost the entire western portion of the state, and the Lehigh Valley, so far as the manufacture of iron is concerned, acknowledges herself greatly outstripped by her western rival.

But during this same period of time, an infant industry has been born here in the Lehigh Valley and grown to such gigantic proportions as to attract attention and command the lasting respect of the entire commercial world. And while the glow of her open furnaces at night is less frequent, this indication of the diminution of one of her industrial activities is to-day many times outweighed by the ceaseless dropping from scores of rotary kilns of thousands of barrels daily of white-hot clinker, and by the din and roar of the grinding machinery of more than twenty cement plants, busy in converting this clinker into a structural material, second only to steel itself in importance. This might be truly called the age of steel and cement.

The object of this paper is to give a brief description of the geological occurrence of the cement materials, and a short history and description of the methods by which cement is manufactured from them.

II. GEOLOGY.

PHYSIOGRAPHY.

Lehigh and Northampton counties, Pa., occupy a portion of the great valley extending across the northern part of New Jersey and the southeastern part of Pennsylvania, in a northeasterly-southwesterly direction and included between the Blue Mountain range on the north and the Highlands of New Jersey and the Durham and Reading Hills of Pennsylvania on the south. That portion of the Blue Mountain range to the north of the valley

known as the Kittatinny Range is an even crested ridge having a maximum elevation of 1,600 feet above tide. The range of hills on the south of the valley is somewhat more uneven in character but presents a more or less continuous barrier, nowhere reaching an altitude of more than 1,000 or 1,200 feet above tide.

The summits of these two ranges are considered to be remnants of a once continuous and nearly level surface or pene-

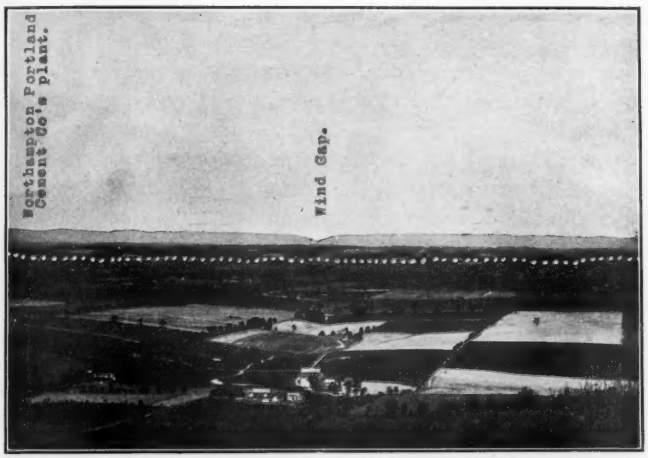


FIG. 1. View from the summit of Chestnut Hill near Easton, Pa., looking northwest across the Kittatinny Valley to the Kittatinny Range. The Wind Gap, which is thirteen and one half miles distant, appears as a distinct notch in the range. The dotted line shows approximately the position of the cement belt, just beyond which are the hills composed of Hudson River slates, which here, generally speaking, have an elevation of three or four hundred feet above the limestone valley which occupies the foreground.

plain which, at the close of the Cretaceous period, was of wide extent throughout the Appalachian region. This peneplain was the result of a base-levelling process which was in progress during the entire Mesozoic period and which resulted in bringing the entire land surface down to a monotonous or nearly level surface, out of which protruded a few prominences such as the Pocono

Knob. This level surface, or plain of erosion was the result of the stream and atmospheric erosion which continued during the entire Mesozoic era, and which accomplished a complete cycle of erosion, producing what is known in the eastern portion of Pennsylvania and northern New Jersey as the Kittatinny Peneplain, remnants of which are to be found in the Pocono plateau and in the nearly horizontal even crested ridges to the south, notably the Kittatinny range and the ridges south of the great valley already mentioned. At this time the rivers of the region flowed lazily over this low-lying, nearly level plain, to the sea. Their work of degradation was accomplished. This plain of erosion is the eastward extension of the Harrisburg Peneplain of Campbell.

At the close of the Cretaceous period there came a general uplift of the entire Appalachian region. Throughout the region under consideration this elevation amounted to 1,200 or 1,400 feet. The rivers were given a new lease of life, and went at the task of again reducing the land area to the sea level with the result that they have accomplished only a part of it, viz., an erosion of the softer or more soluble rocks of the valleys, leaving the harder rocks standing up as ridges, the summits of which, as already explained, constitute remnants of the old Kittatinny peneplain. Since the first general uplift there are indications of a smaller elevation of some 200 feet.

The broad valley between the Kittatinny range on the north and Lehigh Mountain, with its northeastern and southwestern extensions on the south, is a part of the Kittatinny valley. This valley consists of two parts—a southern covering a limestone and dolomite area and having a general altitude of about 400 feet above tide, and a northern coextensive with the slate hills region. The latter part, owing to the less soluble and more resistent character of the slate rock, has a general elevation of from 600 to 800 feet above tide, or an elevation 200 to 400 feet above that of the southern limestone-dolomite area. These topographical features are well illustrated by Fig. 1.

STRATIGRAPHY.

The Pre-cambrian Rocks.—The geologic column in Lehigh and Northampton counties begins at the bottom with the pre-cambrian rocks which compose the southern range of hills.

The rocks of this Terrane comprise: (1) Dark colored, basic, hornblende and augite gneisses, sometimes more or less altered to epidote or chlorite; (2) light colored, highly feldspathic, more or less granitoid gneisses, both cut by (3) numerous intrusions of granite and pegmatite and by (4) an occasional dyke of diabase or augite-syenite.

The Basal Conglomerate.—Following the pre-cambrian gneisses and lying unconformably upon them is the basal conglomerate or quartzite series varying in thickness from a few feet to three or four hundred feet in thickness.

The basal quartzite series in Lehigh County begins at the bottom with a few feet of coarse conglomerate, which is followed by a typical arkose. This then grades into dense bluish or grayish quartzite having interstratified with it a few feet of impure, fine-grained quartzite containing scolithus. The uppermost member of the series is a very fine-grained, almost jaspery, frequently highly ferruginous quartzite. The series is the northeastern extension of beds which in York County have been called by Mr. C. D. Walcott, the Hallam quartzite and is the equivalent of the Hardiston quartzite of Kümmel and Weller in northern New Jersey. The basal quartzite constitutes the lowest member of the cambrian.

The Kittatinny Dolomites and Dolomitic Limestones.—The basal quartzite series is succeeded by some 3,000 feet of dolomites and dolomitic limestones for which the name Kittatinny dolomite has been proposed, and which Kümmel and Weller have shown to represent the entire cambrian, lower middle and upper. The lower portion of this 3,000 feet is rather heavy bedded. Individual beds are occasionally oölitic and others at times contain bands of black flint several inches thick. The very lowest beds are more or less indurated by infiltrated silica.

The following are analyses of specimens taken from quarries about Easton.

	Per Cent.	Per Cent.	Per Cent.
$CaCO_3$	54.40	53.40	54.75
$MgCO_3$	42.40	40.54	42.36
Fe and Al	2.22	2.92	2.16
SiO_2	1.84	3.52	1.00

The Trenton Limestone.—Towards the top of this 3,000 feet of dolomites thin beds of sandy or slaty material make their appearance, sometimes extensively ripple-marked. Occasional beds of true limestone appear which become more and more numerous until finally the limestone beds predominate and the Kittatinny dolomite series passes over into a series of 100 to 300 feet of beds, essentially non-magnesian limestone but still containing occasional magnesian or dolomitic beds. The quarrymen distinguish between these dolomitic rocks and the limestone by their difference in hardness, calling the dolomitic rocks "hard limestone" and the purer limestone "soft limestone." These three hundred feet of essentially limestone beds, following the 3,000 feet of Kittatinny dolomites, contain a distinctive Trenton fauna and have therefore been assigned to that epoch.

The Trenton rocks of this region fall naturally into two subdivisions: (1) A lower, consisting of nearly pure limestones, and (2) an upper, consisting of more or less highly argillaceous, slaty limestones. This upper member furnishes most of the material for the manufacture of cement, and throughout the region is called "cement rock." The economic importance of the Trenton series warrants a more detailed description.

(1) The Lower Trenton or Limestone Horizon.

The rocks of this horizon vary considerably in color, texture and chemical composition. In color they range from light gray to a dark slate. In texture, all gradations from a very finely granular, almost slaty rock to a rather coarsely granular one can be found. Nowhere do they show an aggregate thickness of over 100 feet. They are essentially pure limestones and furnish much of the material used to raise the lime

content of the cement rock to the proper proportion in the cement mixture. In chemical composition the chief variations consist in the amounts of carbonate of lime and carbonate of magnesia which they contain. The former compound varies between 80 per cent. and 97 per cent., but occasionally falls as low as 70 per cent. The latter compound varies from 1.5 per cent. to nearly 3 per cent. in the purer limestones, while in a few other beds it rises as high as 20 per cent. or even more. The occurrence of these magnesian limestones among the others causes much trouble in quarrying (see Fig. 2).

Some idea of the rapid variation in the relative proportions of lime and magnesia may be obtained from the twenty-nine analyses given below. Each of these twenty-nine analyses represents a separate individual bed. The samples were taken from three quarries located about two miles west of Catasauqua, and illustrate very well the changes in chemical composition of the lower Trenton limestones. The beds from which the samples were taken aggregate about 75 feet in thickness, and the samples were taken as numbered from below up. Only the percentages of carbonate of lime and magnesia are given, the remainder being silica, alumina, and iron.

ANALYSES OF THE LOWER LIMESTONES OF THE TRENTON SERIES.

No.	$CaCO_3$	$MgCO_3$		No.	$CaCO_3$	$MgCO_3$	
1	89.50	1.92		16	92.90	2.10	
2	92.20	2.60		17	88.90	2.27	
3	94.00	2.27		18	91.30	1.92	
4	88.20	1.92		19	92.10	1.92	
5	87.80	1.51		20	84.80	1.52	
6	93.40	1.92		21	90.60	2.27	
7	91.00	3.20		22	65.80	19.49	4′ thick.
8	70.60	12.94	2′ thick.	23	94.00	1.76	
9	94.40	1.92		24	90.50	2.66	
10	72.20	11.18	4′ thick.	25	92.70	2.66	
11	66.50	18.73	1′ 6″ thick.	26	51.30	22.09	2′ thick.
12	90.30	2.43		27	84.70	2.60	
13	92.00	2.86		28	70.90	1.92	
14	96.60	1.51		29	88.90	2.10	
15	95.10	1.92					

The principal drawback in the manufacture of cement in the Lehigh region, so far as the materials from which it is manu-

factured are concerned, is the lack of an abundance of non-magnesian, pure limestone. In the majority of cases the rock is too low in lime, and the deficiency must be made good by the addition of limestone containing as small a percentage of impurities as possible. In no case should it contain over 4 per cent., or at the very most 5 per cent. of magnesium carbonate. Too much magnesia in Portland cement not only reduces its tensile strength but causes it to expand and crack after setting. No cement should contain over 3 per cent. of magnesia. Any limestones carrying over 4 per cent. of magnesium carbonate are styled "high magnesian limestones," and are studiously avoided by the manufacturer. The constant thorn in the side of the quarrymen for

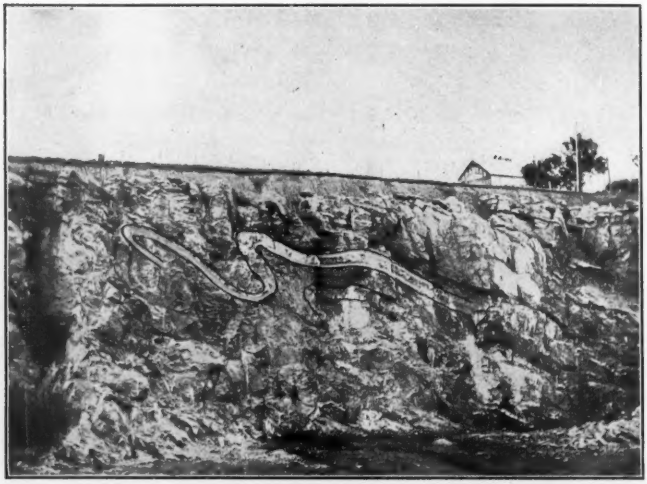


FIG. 2. View in the Lawrence Cement Co.'s quarry north of Catasauqua looking east showing lighter colored dolomite beds interstratified in the limestone.

the mills which are deriving their supply of limestone from neighboring quarries, is the all too frequent occurrence of beds of high magnesian rock among the beds of purer limestone. These must be carefully sorted out, thus increasing the expense of

quarrying. As a result of this poverty of high-grade limestone throughout the region, many of the mills are forced to obtain their supply from distant points, *e. g.*, northern New Jersey or the Lebanon Valley. Lebanon Valley limestone costs $1.10 per ton delivered at the mill, and runs 98 per cent. carbonate of lime. The coarsely crystalline, pre-cambrian limestone of northern New Jersey can be obtained at about the same price, and is equally pure. The native limestone when purchased from neighboring quarries costs 60 cents per ton at the mill, but averages only 88 per cent. carbonate of lime. This limestone, being lower in lime, must be added in larger quantities, and is therefore in reality no cheaper. As elsewhere stated, the mixture of raw materials should contain 75 per cent. carbonate of lime. For each 1 per cent. less than this amount, there must be added 5 per cent. of pure carbonate of lime. For illustration let us suppose that the cement rock from a given quarry contains 68 per cent. carbonate of lime. To this rock the manufacturer would have to add 35 per cent. of pure limestone or a little over one ton of limestone to every two tons of cement rock, and a correspondingly larger amount of low grade limestone.

Recognizing the very great desirability of being able to use the high magnesian limestones in the manufacture of Portland cement, Mr. Richard K. Meade, chemist for the Dexter Portland Cement Company at Nazareth, has recently invented a process for making cement, superior in strength to the best grades of Portland cement, out of limestones containing preferably from 5 per cent. to 20 per cent. of magnesia. The principle which lies at the foundation of his discovery consists in the conversion of the magnesia in the cement to the oxychlorid of magnesia, which compound is akin to the oxychlorid of zinc, much used by dentists as a cement in the filling of teeth.

This oxychlorid of magnesia has cementing qualities greatly superior to those of the best grades of Portland cement, and would consequently add materially to its strength, and in direct proportion to the amount of it present. The process (quoting from the patent, No. 866,376, dated September 17, 1907), "consists in mixing with 'cement rock' sufficient high magnesian

limestone to bring the lime and magnesia in the mixture up to the proper ratio to the silica, iron oxid and alumina, the preferred ratio of the calcareous material to the argillaceous material being approximately 2 to 1. The mixture is then ground to an impalpable powder, burned to the point of incipient vitrifaction and a small percentage, preferably from one to ten per cent. by weight of calcium chlorid is added to the clinker and the mixture ground to the requisite fineness. The proportion of calcium chlorid to the mixture will depend upon the percentage of magnesia in said mixture, satisfactory results being obtained by the addition of 2 per cent. of calcium chlorid to a cement mixture containing eight per cent. of magnesia. Where the cement mixture contains a larger percentage of magnesia, a proportionally larger amount of the chlorid will be required.

"In place of calcium chlorid I may employ other chlorids, preferably metal chlorids, such for example as sodium, or other alkaline chlorids, magnesium, or other chlorids of metals of the magnesium group, barium, or other alkaline earth chlorids; the various chlorids being equivalents of the calcium chlorid mentioned, in the practice of my process.

"The calcium or other chlorid employed may be added to the materials used in the manufacture of cement before grinding, or before burning, or it may be added to the clinker at any time during the process of grinding, or it may be added to the cement before being used, or to the water or other material mixed with the cement; it being sufficient that the chlorid be incorporated with the high magnesian limestone cement at any time prior to the crystallization or setting of the latter in use, and any such incorporation is deemed to be within the spirit of my invention, and the scope of the protection for which I have made application.

"Gypsum or plaster of paris may be added to the materials employed in producing the cement at any time either before or after grinding if found necessary in order to regulate the set. The calcium chlorid, or its equivalent however serves this purpose, so that the addition of gypsum or plaster of paris is in most cases wholly unnecessary.

"In use, the calcium or other chlorid employed combines with

the free magnesium oxid in the cement when the latter is mixed with water, and not only renders the latter innocuous, but also forms with it an oxychlorid compound having itself great cementing properties. The resulting mixture of Portland cement and oxychlorid cement has greater strength and binding properties than the Portland cement itself. It will thus be seen that in the practice of my invention I am not only able to utilize high magnesian limestone in the manufacture of cement, thereby cheapening the cost of such manufacture, but I am also enabled to produce by such use a superior quality of cement."

If Mr. Meade's discovery proves a success in actual practice, the significance of it to cement manufacturers—in the Lehigh region, is most apparent. It would end for them their hitherto rather precarious search for large bodies of high grade limestone. And instead of importing gypsum to retard the set of their cement, they could with less expense import from the salt producing region of New York chlorid of lime which would serve the purpose not only of retarding the set of the cement but convert the magnesia in it into the desired oxychlorid. The writer is informed by Mr. Meade that sand briquettes (1 part cement to 3 parts sand), made of cement manufactured according to his process, at the end of seven days stood a test of 300 lbs., while the best grades of Portland are not expected to reach over 250 lbs. At the end of six months they stood a test of 450 lbs., thus showing no retrogression. The cement from which these briquettes were made contained a little more than 8 per cent. of magnesia. As yet no attempt has been made to manufacture high magnesian cement by this new process on a commercial scale.

(2) The Upper Trenton, or Cement Rock Horizon.

The rocks of this upper member of the Trenton series are quite uniformly of a slaty character (see Fig. 3). They may be, however, of a distinctly granular texture. In color they range from drab to almost black. Frequently on the slaty cleavage surfaces the rock exhibits a characteristic sheen, due to the presence in considerable quantities of free carbon, and occasionally the rock

resembles an impure earthy coal. The bedding in this upper part of the Trenton is rarely distinguishable, having been obliterated (if it were ever very apparent) by the mashing to which the beds have been subjected, and being soft by nature they have apparently yielded in part by flowing. The dip of the slaty cleavage is quite uniformly to the south at angles varying from 5°

FIG. 3. View north of the Atlas Cement Co.'s quarry looking northeast, showing the slaty character of the rather highly argillaceous limestone (cement rock). The slaty cleavage dips to the south. The gentle undulations visible in the cleavage are produced by the cleavage passing at an angle across the beds, which here dip at an angle of 40° to the north.

to 30°. The maximum thickness of these beds does not appear to exceed 200 feet. Chemically considered, they are intimate mixtures in varying proportions of carbonate of lime and clay, with the carbonate of lime usually in excess, but gradually diminishing from below upwards as the Hudson River slates are approached. The carbonate of lime, broadly speaking, varies between 50 per cent. and 75 or 80 per cent. (See sections, p. 54.)

This slaty limestone series begins as thin slaty seams, intercalated between the beds of purer Trenton limestones underlying

them, sometimes constituting beds of true slate with no lime content whatever, but usually containing a considerable proportion of $CaCO_3$ and having the distinctly slaty character quite common to the cement rock. These thin seams of slaty limestone increase in thickness and in frequency of occurrence from the middle of the lower Trenton limestone series upwards, until finally the beds of slaty, impure, argillaceous limestones predominate and the purer limestone strata become of decidedly secondary importance and finally disappear altogether.

The variation in chemical composition of the beds which form this upper member of the Trenton series is well illustrated in the thirty analyses given below, which were made from as many samples taken ten feet apart in sinking three drill holes, each to a depth of 100 feet through the beds which lie immediately on top of the 75 feet of purer limestones, analyses of which are given above.

ANALYSES OF THE UPPER, ARGILLACEOUS BEDS OF THE TRENTON SERIES (CEMENT ROCK).

Drill Hole No. 1.

Depth.	10′	20′	30′	40′	50′	60′	70′	80′	90′	100′
SiO_2	18.58	19.76	22.30	21.84	13.30	6.08	12.40	20.90	12.82	15.54
Al, Fe_2O_3	6.88	7.48	7.60	7.02	2.68	1.80	2.88	4.50	3.26	3.56
$CaCO_3$	60.76	66.51	63.17	64.08	68.41	86.28	79.06	67.51	74.73	70.76
$MgCO_3$	3.06	3.36	4.18	4.12	14.11	4.06	4.36	5.28	7.90	8.54

Drill Hole No. 2.

SiO_2	20.16	17.12	15.48	15.44	15.60	15.14	23.06	19.42	11.58	18.46
Al, Fe_2O_3	6.70	8.94	7.74	8.56	7.92	7.74	8.48	7.32	4.40	5.76
$CaCO_3$	64.26	65.79	69.49	68.32	69.31	68.95	61.55	66.03	76.35	59.93
$MgCO_3$	4.00	4.70	4.38	4.36	4.29	4.55	3.55	4.23	6.42	14.32

Drill Hole No. 3.

SiO_2	19.00	20.40	24.90	19.78	18.42	15.96	23.90	18.32	15.14	13.10
Al, Fe_2O_3	9.34	8.52	8.64	7.82	8.86	7.66	8.26	7.48	7.30	4.44
$CaCO_3$	64.89	64.62	60.29	65.34	64.62	68.87	58.75	67.33	70.58	72.29
$MgCO_3$	4.14	4.24	4.11	4.05	4.47	4.30	3.98	4.39	4.29	8.60

The following are some additional analyses from other localities showing variations in chemical composition of the limestone of the region.

Analysis No. 1.—Rock high in lime, requiring the addition of some clay or slate before burning.

SiO_2	11.92
Al + Fe	4.56
$CaCO_3$	78.60
$MgCO_3$	3.07
	99.07

Analysis No. 2.—Rock low in lime, requiring addition of limestone before burning.

Silica	14.08
Al + Fe	7.50
$CaCO_3$	73.12
MgCO	4.56
	99.26

Analysis No. 3.—Rock low in lime.

Silica	15.73
Al + Fe	7.92
$CaCO_3$	70.75
$MgCO_3$	3.77
	98.17

Analysis No. 4.—Rock still lower in lime.

SiO_2	23.03
Fe + Al	8.74
$CaCO_3$	62.02
$MgCO_3$	4.68
	98.47

Analysis No. 5.—Showing proper composition of a mixture of cement rock and slate or cement rock and limestone ready for burning.

Silica	13.32
Al + Fe	6.67
$CaCO_3$	74.97
$MgCO_3$	3.84
	98.80

Analyses Nos. 1 and 2 are from the same quarry.

Analyses Nos. 3 and 4 are from another quarry.

Analysis No. 6.—This rock requires the admixture of neither lime nor slate.

SiO_2	13.88
$Al + Fe$	6.58
$CaCO_3$	75.75
$MgCO_3$	2.70
	98.88

But from the same quarry as No. 6, another stratum gave Analysis No. 7.

SiO_2	15.31
$Al + Fe$	7.49
$CaCO_3$	71.69
$MgCO_3$	3.91
	98.40

The Hudson River Slate.—The Trenton limestones are succeeded by a much thicker series of true clay slates. Their actual thickness can not be stated but it is doubtless several thousand (5,000?) feet.

Unlike the boundaries between dolomite and limestone, or that between the limestone and the cement rock, which are poorly defined, on account of the intercalation of the upper beds of one series with the lower beds of the following series, the boundary between the cement rock and the slate proper is sharply defined and the transition is sudden and abrupt. All of the rocks of the Trenton series, even the very poorest in lime, effervesce rapidly with dilute hydrochloric acid while the slates do not, and the acid test can be used to advantage in determining the boundary between these two formations.

A single bed of limestone has been found interstratified with the slates and that is 100 feet or so above the cement horizon. It does not appear to be continuous but seems to consist of a series of lenticular masses reaching a maximum of 50 feet in thickness. It outcrops at a point one mile northwest of Cementon on Spring Creek and at two points two miles west of Bath on Catasauqua Creek. At the latter localities it is quarried and burned for lime for fertilizing purposes. It is impure and dolomitic in character.

The slate also contains beds of sandy material approaching greywacke in appearance which occur apparently about midway in the series.

Oneida and Medina.—Succeeding the Hudson River slate series are the Oneida and Medina beds already referred to as constituting the backbone of the Kittatinny Range. Together they have a thickness at the Lehigh Gap of about 1,500 feet. They consist of silicious and pebbly sandstones and conglomerates, the sandstones both white and red in color, predominating and both more or less altered to quartzites, by reason of which they have withstood erosion even more successfully, perhaps, than the crystalline pre-cambrian ranges to the south of them.

In the present paper no mention need be made of the many thousands of feet of Silurian, Devonian and Carboniferous sediments (about 20,000 feet in all) which follow the rocks of the Oneidá and Medina stages.

STRUCTURE.

Deformation of the Region.—At the close of the Carboniferous period came the great Appalachian revolution, which folded the 30,000 to 40,000 feet of Palæozoic sediments up into a more

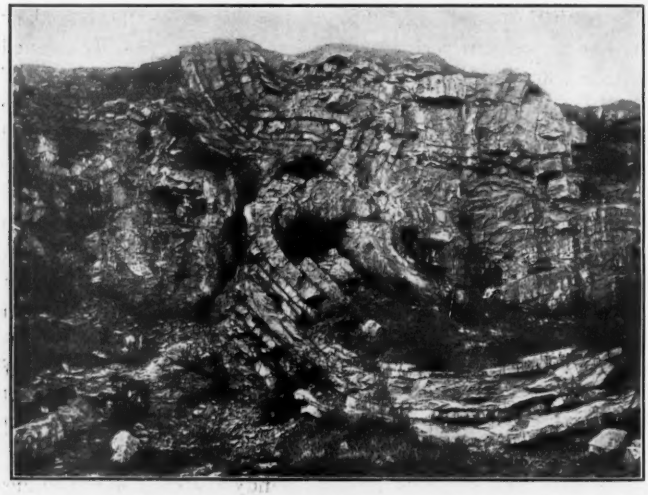


FIG. 4. Fold in the lower Trenton limestone at the Coplay Cement Company's quarry near Coplay. The view looks southwest along the strike of the beds.

or less complex series of folds, the axes of which in the region under consideration (as generally throughout the southeastern part of the state) trend northeast and southwest. This folding was in a direction from the southeast toward the northwest, the titanic character of which can best be judged of by observing the effect which it has exerted upon the rocks of the region.

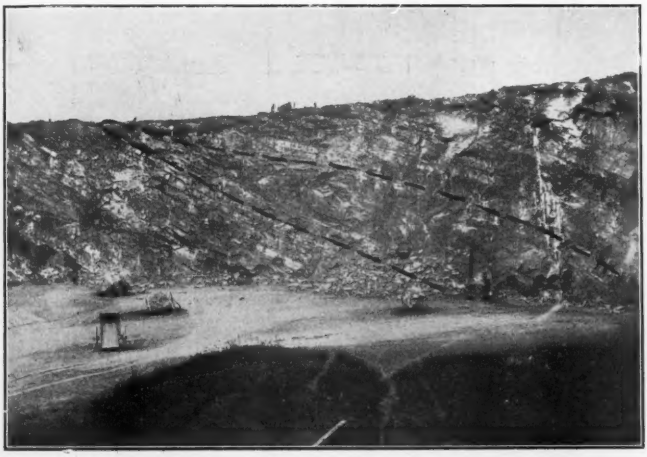


FIG. 5. Limestone quarry near Guth's Station, Lehigh County, looking east, showing sharp fold in the rocks overturned to the north.

In the dolomite area the rocks being heavier bedded, stronger and more resistant, yielded more by slight dislocation along joint plains and by occasional faulting, although this is almost unknown in the Cement Belt proper. The cambrian dolomite series was the competent structure by means of which the compressive stresses were transmitted a score or two of miles to the northwest. The softer limestones with their occasional interstratified beds of dolomite yielded by folding, attended by some faulting and more or less flowage of the softer beds. It is in these beds that the extreme character of the folding is most clearly visible. The folds are usually closely appressed and frequently overturned to a greater or less degree to the northwest and are occasionally

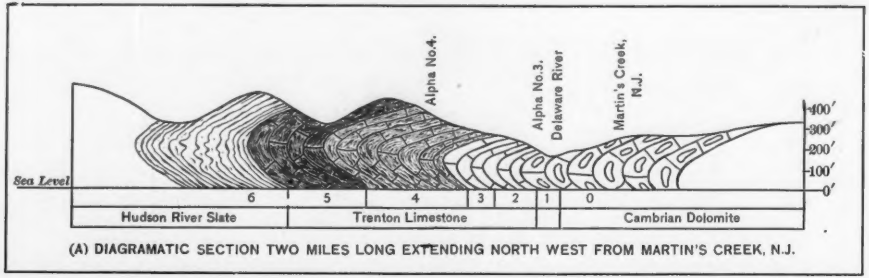
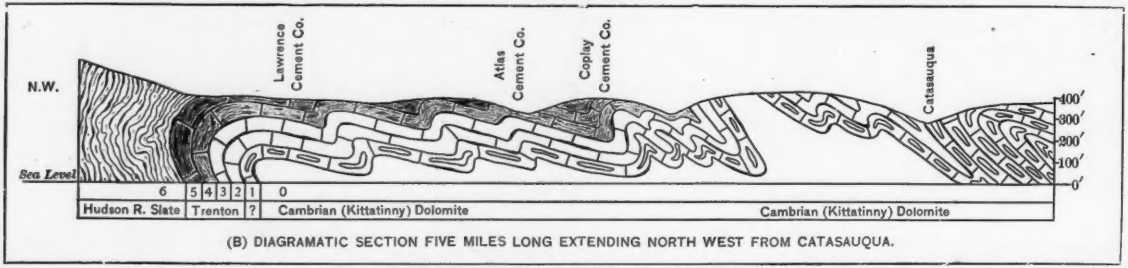


FIG. 6. Section A. (See Map opp. p. 56.) Showing overturned fold in the Cambrian dolomitic limestones, Trenton limestones and Hudson River slates. 0 and 1 = Dolomitic Limestones; 2 and 3 = Lower Trenton, rocks high in lime; 4 = Cement Rock, Upper Trenton, averaging 70 per cent. to 80 per cent. $CaCO_3$; 5 = Cement Rock, Upper Trenton, carrying less than 70 per cent. $CaCO_3$; 6 = Hudson River Slates.



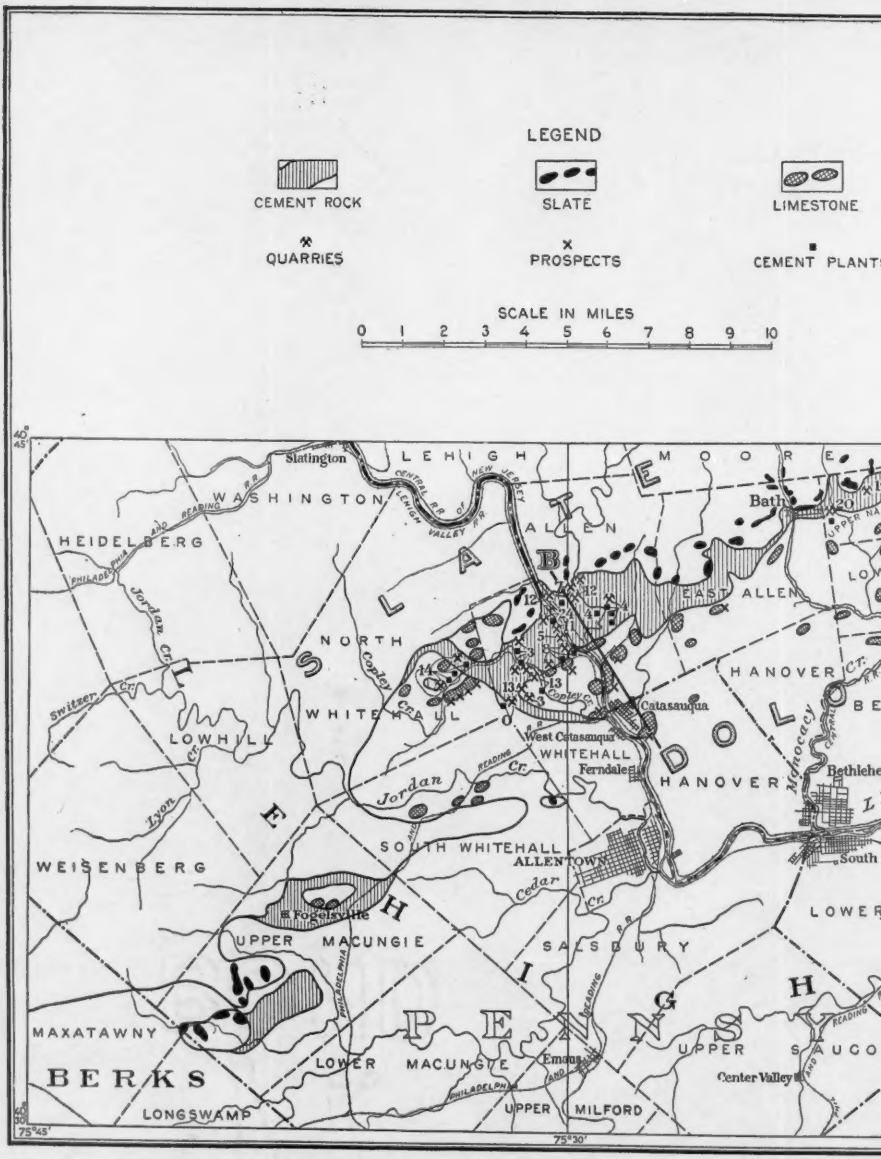
Numbers indicate same as in the Martin's Creek section.

FIG. 7. Section B. (See Map opp. p. 56.)

Numbers indicate same as in the Martin's Creek section.

FIG. 7. Section B. (See Map opp. p. 56.)

PLATE II



MAP OF THE CEMENT BELT SHOWING LOCATION

BELT SHOWING LOCATION OF PLANTS, QUARRIES AND OUTCRO

LOCATION OF PLANTS, QUARRIES AND OUTCROPS

recumbent in this direction. Estimates made in one or two quarries in the limestone belt north of Catasauqua, show a crustal shortening of 6 to 1. That is to say, six miles of originally horizontal strata were mashed together into a single mile. The complex character of the folding under such conditions can easily be imagined.

In the cement and slate belts alike the rocks are of that weak yielding character which resulted not only in extreme folding but in more or less flowage, so much so that the original bedding is usually no longer distinguishable. Instead there is everywhere present that distinct slaty cleavage which usually dips at a small angle to the south. At times, however, faint traces of the bedding planes can be distinguished, through the folds of which the cleavage plains pass at all angles.

The general character of the geologic structure may be observed in the two structure-sections A and B by Fig. 6. The position of these sections is indicated on the accompanying map, Plate II.

DISTRIBUTION AND ORIGIN OF THE CEMENT ROCK.

Distribution.—The accompanying map shows the areal distribution in Lehigh and Northampton counties, of the rock used in the manufacture of cement, both of the Portland and Rosendale varieties. It will be seen to extend as a continuous zone or belt of varying width in a southwesterly direction across Northampton County from the Delaware to the Lehigh River, at which latter point it reaches a maximum width of about two miles; crosses the Lehigh River, into Lehigh County and ends abruptly at a point four and one half miles due west from Coplay. Farther to the southwest in the townships of Upper and Lower Macungie are two isolated patches.

Origin.—The conditions under which the deposition of the Trenton series, both lower and upper, took place, may be described as follows: First came the deposition of the lower member of the series by an accumulation of organic calcareous remains, chiefly as it seems in the form of small crinoid stems which at times may be seen on the weathered surfaces of the rock in great

EXPLANATION OF PLATE II.

The vertically shaded area which extends across the map from the southwest to the northeast corner is the so-called cement belt, *i. e.*, the outcrop of the member of argillaceous limestones which intervenes between the underlying limestones and the overlying Hudson River slates. The dip varies as may be seen from the sections A and B, but the general downward trend carries the cement rocks below the surface towards the northwest.

The solid black areas are slate, the cross-hatched areas limestone. The numbers indicate the location of the various properties. Below is a list of these properties.

List of Cement Properties.

*0. Allentown Portland Cement Co., W. Catasauqua, Pa.
1. Alpha Portland Cement Co., Alpha, N. J.
*2. Atlantic Portland Cement Co., Stockertown, Pa.
3. American Cement Co. of Pa., Egypt, Pa.
4. Atlas Portland Cement Co., Northampton, Pa.
5. Atlas Portland Cement Co., Coplay, Pa.
6. Bath Portland Cement Co., Bath, Pa.
7. Bonneville Portland Cement Co., Siegfried, Pa.
8. Coplay Cement Manufacturing Co., Coplay, Pa.
9. Dexter Portland Cement Co., Nazareth, Pa.
10. Edison Portland Cement Co., Stewartsville, N. J.
11. Hercules Cement Co., Coplay, Pa.
12. Lawrence Cement Co. of Pa., Siegfried, Pa.
13. Lehigh Portland Cement Co., West Coplay, Pa.
14. Lehigh Portland Cement Co., Ormrod, Pa.
15. Alpha Portland Cement Co., Plant No. 3, Martin's Creek, Pa.
16. Alpha Portland Cement Co., Plant No. 4, Martin's Creek, Pa.
17. Nazareth Cement Co., Nazareth, Pa.
18. Northampton Portland Cement Co., Stockertown, Pa.
19. Penn Allen Portland Cement Co., Bath, Pa.
20. Pennsylvania Cement Co., Bath, Pa.
21. Phoenix Cement Co., Nazareth, Pa.
*22. Quaker Portland Cement Co., Sandt's Eddy, Pa.
23. Vulcanite Portland Cement Co., Vulcanite, N. J.
24. Whitehall Portland Cement Co., Cementon, Pa.

* In process of erection.

numbers. These remains were deposited in comparatively deep water at such a great distance from the land, that not even the finest silts and muds were transported thither, thus forming comparatively pure lime accumulations. The beds, exclusive of those few of magnesian limestone interstratified with them, range between 80 per cent. and 96 per cent. carbonate of lime. Then followed a slight shoaling of the sea, attended by a migration of the Ordovician shore line far enough toward the northwest to permit the finest terrigenous materials in the form of impalpable clay muds to mingle and be deposited with the calcareous remains just mentioned. By the commingling of these two ingredients in varying proportions, the different grades of cement rock, both low and high in lime, can be accounted for. The action of the currents would determine in what proportions they would be deposited, and explain the total lack of their deposition at some points.

Then followed a still further shoaling of the sea, which resulted in such a rapid influx of terrigenous materials as to completely destroy the deep, clear-water fauna of the earlier Trenton period, and institute that period of quiet, off-shore sedimentation which continued for a much longer period of time, and resulted finally in the deposition of the several thousands of feet of Hudson River shales.

Succeeding this came an apparently abrupt elevation of the floor of the Ordovician sea, which advanced the shore line of the continent on the southeast to a position a little south of the Kittatinny and Blue Mountain ranges and parallel with them. The coarse, pebbly sandstones and conglomerates of the Oneida and Medina periods are the ancient beaches and shallow water deposits of early Silurian time.

III. HISTORY AND ORIGIN OF THE CEMENT INDUSTRY AND DESCRIPTION OF THE METHODS OF MANUFACTURE.

DISCOVERY OF HYDRAULIC CEMENT.

The Romans were the first to use cement in any large way, and their discovery of it was purely accidental. They found that

by mixing the reddish or grayish finely granular or sandy earth, which occurred in thick beds about and under the city of Rome, with lime, that the mixture possessed the valuable property of solidifying into a strongly coherent mass which time had only the effect of still further hardening and that this setting process would continue under water just as well as in the air, in fact that an abundance of water seemed to facilitate the process; that the cement thus made was far more durable than ordinary lime mortar; that mixed with broken stone or crushed tiling it formed a concrete which would outlast the most massive forms of stone masonry and continue to harden for centuries.

This reddish granular earth, called "Pulvis Puteolanus," for the reason that it was found abundantly about Puteoli (now Pozzuoli) was the essence of all of the Roman cements and later came to be known as Pozzuolana or Puzzolana. Accurately speaking, this Puzzolana is volcanic dust and fine lapillæ which had been blown from neighboring volcanoes and which had accumulated in thick beds in their neighborhood. This volcanic material when mixed with lime had all of the essential chemical ingredients of the modern hydraulic cements. It was the mere accident of the propinquity of these volcanic ash beds, materials calcined at high temperatures in the vast subterranean kilns of volcanoes, which made the Roman cements so much stronger than all others and which gave them their just reputation. From the time of the Roman Republic down to the discovery of the true nature of hydraulic mortars as exhibited in Portland cement, Puzzolana occupied a unique place.

The first modern hydraulic cements were manufactured in England. In 1759 a civil engineer by the name of John Smeaton, who had been engaged to build the famous Eddystone lighthouse (which had been twice destroyed, once by fire and once by storm), and who for that purpose required hydraulic cement which would withstand the action of sea water, discovered that by burning certain impure limestones containing from 15 to 25 per cent. of impurities in the form of silica and alumina, a suitable hydraulic cement could be produced. From that time on search was made all over England for hydraulic limestones

from which to make this valuable structural material. In 1796 a man by the name of Parker discovered that by burning certain brownish clay-lime concretions called "bald-pates" or "captaria," which were found in the shales of the Island of Sheppey, an excellent hydraulic cement could be produced, and inasmuch as it resembled the ancient Roman cements it was called "Roman cement."

The increasing demand for hydraulic cements, however, combined with the difficulty and expense connected with collecting the necessary amount of captaria, led others to look about for more abundant and cheaper materials. In 1824 Joseph Aspdin, a Leeds bricklayer, took out a patent for an artificial cement which was made by lightly burning a mixture of lime and clay. This he called "Portland Cement" because of its resemblance when hardened to the famous building stone of the Isle of Portland. Two years later, viz., in 1826, Major General C. W. Pasley, who had been appointed lecturer on architecture at the military school at Chatham, began a series of experiments, the object of which was to produce an artificial cement which should be equal or superior to the so-called Roman cement. In this he appears to have been ignorant of Aspdin's cement. In 1830 he succeeded in making an article which experimentally proved to give perfectly satisfactory results. The materials used were Medway clay and chalk. The essential differences between these earlier forms of hydraulic cement and the modern were in the degree of calcination and in the thoroughness of the mixture of the ingredients. In earlier processes the calcination was not carried, as at present, to the point of incipient fusion, which is now recognized to be one of the essentials in the manufacture of the best grades of Portland cement. In fact that part of the burned material which showed signs of fusion was rejected and in so doing they unwittingly discarded the most valuable product of the kiln. Nor were the materials as finely ground or as thoroughly blended before burning.

From these beginnings sprang the Portland cement industry, which was at first confined to England, but which later spread

to Belgium, France and Germany, and which by 1860 had become well established on the continent.

ORIGIN AND GROWTH OF THE CEMENT INDUSTRY IN THE UNITED STATES.

In the meantime the demand in the United States for hydraulic cements arose more particularly on account of the need for them in connection with the construction of canals, notably the Delaware and Hudson, the Lehigh, the Chesapeake and Ohio. It was quite natural therefore to expect that suitable materials would be sought along the courses of these water-ways, which could be manufactured into the desired product. The search was not fruitless. Excellent hydraulic limestones were discovered at Rosendale and Rondout on the Hudson, at Siegfried and Coplay on the Lehigh, and at Hancock and Cumberland in Maryland. These impure argillaceous limestones were burned in kilns resembling ordinary lime kilns at a temperature sufficient to drive off the carbonic acid, the burned product was ground to a flour and sold in convenient packages as hydraulic cement. At Rondout and Rosendale, N. Y., large quantities of this natural rock cement were manufactured and the article was called "Rosendale Cement," which term has come to be more or less universally applied to all similar natural cements made by calcining natural hydraulic limestones at low temperature and grinding the product, no attempt being made at an artificial mixture. During the interval 1840–1875 the manufacture of these natural rock cements made tremendous strides in the United States.

It was not until after the civil war, however, that true Portland cement became known in this country. From 1865 to 1876 it was imported in small but ever-increasing quantities from Europe, until its value as a constructive material had become well established. About this time a young farmer, David O. Saylor by name, who lived in Lehigh County, Pennsylvania, and who had been engaged in a small way in the manufacture of ordinary natural cement by burning certain argillaceous limestone which abounded in the region, conceived the notion of

manufacturing a true Portland cement. He enlisted the interest and skill of another young Pennsylvanian, John W. Eckert by name, who had but a short time before been graduated from the chemical and mechanical engineering courses at Lehigh University, and together in 1878 they succeeded in mastering the problem in spite of all the mystery and vigilance which surrounded the process, and in the following year (1879) constructed the first Portland cement works in the United States which produced the article on a commercial scale. From this small beginning sprang one of the largest and best established Portland cement concerns in the country, so well known now as the Coplay Cement Manufacturing Company, whose works are located at Coplay, Lehigh Co., where from two to three thousand barrels of cement are manufactured daily.

Shortly after the success of the first project had become assured, other cement companies were formed and began operation along the Lehigh River and in the adjacent townships in Lehigh and Northampton Counties, for which reason this, the original Portland cement producing region of the United States, became known as the "Lehigh Region." But during the last decade the producing area has been much extended eastward across Northampton County to the Delaware River, and over the Pennsylvania border into Warren County, N. J., also in a southwesterly direction to Reading, Pa. Within this district there are to-day some 23 cement plants with capacities ranging from 800 to 35,000 barrels per day and representing a yearly output of over 11,000,000 barrels, which is roughly speaking one half of the total annual production of the United States.

COMPOSITION AND NATURE OF HYDRAULIC CEMENTS.

Portland Cement.—Portland cement is made by grinding together and to a very fine powder, a mixture of clayey and limy substances (the latter always some form of $CaCO_3$). This ground mixture is then burned or calcined to the point of incipient fusion, at which stage of the process is it known as "clinker." This clinker is subsequently ground and the ground

product constitutes Portland cement. The mixture, however, must consist of certain definite proportions of the clayey and limy ingredients. The cementitious value or strength of the cement depends upon the chemical union of all of the lime of the limy ingredient with all of the silica (SiO_2) and all of the alumina (Al_2O_3) of the clayey ingredient, and there should be just enough lime to do this and no more in order to obtain the best results. This is known as the high-lime limit. Any excess of lime above this limit remains as uncombined lime which is perhaps the most common of the dangerous elements in poorly manufactured cement. Also the cement will not be serviceable: (1) if the materials, though present in proper proportions, are not thoroughly ground and intimately mixed; (2) if insufficiently burned; in this case the chemical union of the lime with the silica and with the alumina of the clay is not complete or the two are loosely combined so that a portion of the lime either remains behind as free lime or becomes dissociated from its union with the silica and alumina. In the latter case when the cement is mixed with water the lime slakes, swells and causes the cement to crack or "blow." Cement of this sort is said to be unsound. This unsoundness may be hours, months or years in developing.

According to Messrs. S. B. and W. B. Newberry[1] the cementing principle of Portland cement was first thought to be due to the formation under the intense heat of burning, of two chemical compounds, which later, on coming in contact with water, hydrated and crystallized. These two compounds were determined to be (1) Tri-calcic silicate, $3CaO, SiO_2$ and (2) Di-calcic aluminate, $2CaO, Al_2O_3$. To the first of these compounds was attributed the slow hardening process of cement which extends over a period of months or even years and to which the final strength of the cement is largely due. To the latter was attributed the quicker setting property of the cement which begins to manifest itself possibly a few seconds or at most a few hours after mixing with water.

These conclusions, which are a modified form of Le Chatelier's,

[1] Paper read before New York Section of Society of Chemical Industry, October 22, 1897.

have recently been discredited by the researches of Day and Shepherd,[2] who conclude that there is no such compound as tricalcic silicate, but that the important compound which is responsible for the setting properties of cement is merely a solid solution of lime in calcium orthosilicate.

As previously stated, the raw materials from which Portland cement is usually manufactured, are carbonate of lime in the form of limestone, chalk or marl, and argillaceous matter in the form of clay, slate or shale. Occasionally, as in the region under consideration, nature has provided a mixture of clay and carbonate of lime in the form of an argillaceous limestone, or natural cement rock, which contains so nearly the theoretical proportions of lime, silica and alumina as to require but a small addition of limestone or clay or slate to make an ideal mixture. It may contain exactly the proper amounts of these ingredients, in which case no admixture of any kind is necessary. In the region about Bath and Nazareth in Northampton County, much of the cement rock is of this character. Along the Lehigh the character of the rock is such as to require the addition of some limestone, which is usually taken from the beds immediately underlying the cement rock. On the Delaware River at Martin's Creek the rock is apt to be too high in lime, which necessitates the addition of slate refuse or clay, while in Warren County, N. J., the addition of limestone is necessary, most of which is obtained from Lebanon Valley. In the majority of cases the addition of limestone is necessary.

PROCESSES OF MANUFACTURE.

The earlier processes of manufacture in the Lehigh region were similar to those practiced in England and may briefly be described as follows:

To the finely ground mixture of cement rock and limestone (containing of course the proper proportions of carbonate of lime, alumina and silica) was added enough water to make a rather fluid mass which was known as "slurry." This slurry was spread out on floors and when somewhat hardened by drying,

[2] *Journal American Chemical Society*, September, 1906.

was cut into bricks, which were thoroughly dried in various ways, usually by piling them up loosely along a series of steam pipes. These dried bricks were then burned in kilns, but at a higher temperature than in burning ordinary lime; as a result the bricks were semi-fused to a "clinker." The clinker was crushed, ground to a fine powder between mill-stones, and then constituted cement.

It would be well to explain here that most Portland cements set too rapidly. In order to retard the set two or three per cent. of sulphate of lime, either in the form of gypsum or plaster of Paris, is added usually during the grinding of the clinker, in order to insure its thorough and even mixture with the cement.

Originally the kilns were of the kind known as "dome kilns" which were upright structures resembling somewhat ordinary lime kilns but having more the lines of a blast furnace, which ensured a high temperature (white heat) during burning. Into these kilns the bricks were loaded with alternating layers of coke or coal. After burning the entire charge was drawn, so that the burning process was intermittent.

Another form of kiln came into use later in which the process was continuous. The amount of fuel (which was usually small coal) necessary for a proper calcination of the bricks was small as compared with the amount used in the intermittent kilns. These continuous kilns are known as the Dietsch Kilns, and the process of calcination was accomplished by stages. The working part of the kiln was divided into three chambers, upper, middle and lower. The dried slurry was loaded into the upper or heating chamber from which a portion of it was raked forward from time to time (usually every half hour or so) into the burning chamber, where at the same time fuel was added through separate eyes, and in which the process of calcining took place. From this the clinker was allowed to settle into the lower or cooling chamber which was immediately below and from which it was periodically drawn. The principal reason for the economy of this kiln was the fact that air in passing upward through the heated clinker of the cooling chamber was raised to a high tem-

perature before passing into the burning chamber and on passing out through the heating compartment served to give the dried slurry a high initial temperature. While economical in the matter of fuel, it was expensive in other respects, more particularly in that it needed constant and skilled attention. Neither of these kilns are at present in use in the Lehigh region, although they might have been seen in operation ten years ago.

The Coplay Cement Manufacturing Co. at Coplay is the pioneer Portland cement concern of the country. After the death of its founder, David D. Saylor, his associate, John W. Eckert,

FIG. 8. Plant of The American Cement Company of Pennsylvania, near Egypt, Lehigh Co., showing arrangement of buildings. The coal house is detached in order to prevent damage to the rest of the plant in case of explosion of coal dust. The plant has a battery of eight kilns, as can be seen from the number of stacks.

united with Robert W. Lesley in forming the American Cement Co. and the plants of these two companies furnish very interesting illustrations of all of the different processes which have been employed in the United States, from the very beginning.

The method of manufacture as at present practiced throughout the region including the manner of quarrying the rock can be briefly described as follows:

Many of the quarries are located on hillsides and have long low working faces from which the rock is shot down in benches. Occasionally the quarries take the form of a pit which extends vertically down to the depth of one hundred or more feet, the depth depending upon the age of the quarry.

Inasmuch as the individual beds vary considerably in their lime content, it becomes a problem to select from different parts of the quarry such a mixture of rock as, when ground, shall approach most closely the ideal mixture. Usually a varying amount of pure limestone, slate or clay from a neighboring or distant quarry must be added to produce a well-balanced mixture, while more rarely all of the necessary materials can be selected from the same quarry. Sometimes the rock is loaded into small cars which run from the quarry face in a series of temporary tracks which radiate to different parts of the quarry from a convenient point, thereby facilitating a mixture of the different grades of rock in the quarry. The loading is accomplished by hand or rarely by steam shovel and the cars run by gravity or are drawn by mules or cable or pushed by hand to the mill. At other times an over-head tram is employed.

At the mill the rock is crushed usually in gyratory crushers, then dried in rotary driers to which later the necessary amount of limestone or slate, also previously crushed and dried, is added. After further reduction the mixture passes to ball mills and from them for its final reduction to tube mills, after leaving which it is conveyed to storage bins preparatory to feeding into rotary kilns. In some instances instead of the ball and the tube mills the reduction is accomplished by the Griffin or Huntingdon mill. The mixture when ready for roasting has a fineness such that from 80 to 90 per cent. of it will pass a 100-mesh sieve. The most recent development in the form of pulverizing machinery, is the Fuller mill, which will with the same horse-power grind about 40 per cent. more material than the Griffin mill. It bids fair to

replace all of the other forms of grinding machinery. Some idea

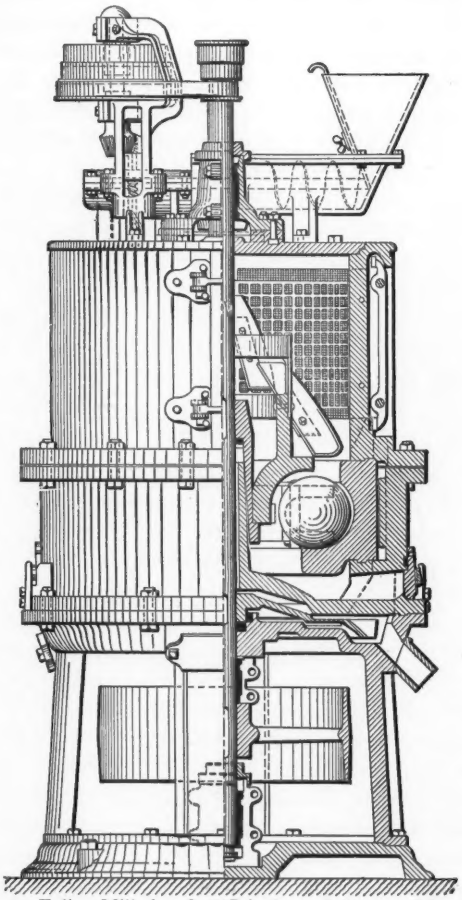


FIG. 9. Fuller Mill for fine Grinding of Cement Materials.

of the arrangement of the mill may be obtained from the accompanying figure (Fig. 9).

At present the calcining of the ground raw material is accomplished in rotary kilns.

The growth of the cement industry in the United States within the past ten years has been due largely to the introduction of the rotary kiln, which was invented by Ransom in England, about twenty-two years ago, but was never successfully operated by its inventor. It was left to the skill and persistency of American mechanical engineers to add the last and greatest impulse to the industry. In 1888 the Atlas Portland Cement Company at Northampton, Pa., installed the first rotary kiln, and after much experimenting, succeeded in operating it successfully. This kiln is a steel cylinder, six or seven feet in diameter at one end and tapering somewhat toward the other. As used up to a few years ago, the kilns were about six feet in diameter and sixty feet long. They were mounted then as now in a slightly inclined position, the inclination being about three-fourths of an inch to a foot. The kiln is lined with fire brick (or occasionally with brick made of cement clinker) to withstand both the high temperature and to resist the corrosive effect of the fused rock. This great tube is mounted in two or more riding rings, each ring on two or four idlers, and made to rotate slowly at the rate of about one revolution in ten minutes. The ground mixture is fed in at the upper end by a screw conveyor, protected by a water jacket. As the kiln slowly revolves the ground rock works its way down into the "fire zone" toward the lower end of the kiln, and is there reduced to a semifused condition and in this condition passes out at the lower or discharging (larger) end in the form of white hot clinker. This lower end of the kiln projects into a movable hood which acts as a shield to protect a nozzle-like burner through which finely pulverized bituminous coal is forced by air blast. This finely pulverized coal ignites with a series of explosions, producing a temperature in the firing zone of about 2,500° F.

In the 60-foot kiln not more than 25 per cent. of the heat developed is actually utilized in the burning of the clinker, the remaining 75 per cent. being lost. In modern practice experiments are being made with two methods for saving some of this wasted heat:

1. The lengthening of the kiln, thus giving the material a longer time in which to absorb the heat, and at the same time greatly increasing its capacity.

2. Passing the gases of the kiln through upright boilers and then through an economizer. This latter experiment has yielded little of practical value, while the first has proven a success, and has accomplished the saving in heat which its originator, Mr. Thomas A. Edison, predicted it would. As a result many of the plants of the region are installing kilns 120 or 140 feet in length. The Edison Portland Cement Co. at Stewartsville, N. J., began by installing four 150-ft. kilns. The Alpha Portland Cement Co. have installed ten 140-ft. kilns in their new plant at Martins Creek. The Dexter Portland Cement Co. at Nazareth is installing 120-ft. kilns, while other plants throughout the region are installing kilns varying in length from 110 to 140 feet. It has now been demonstrated by actual experience that the average capacity in barrels per day is as follows: for a

60-foot kiln is 200 barrels.
100-foot kiln is 400 barrels.
120-foot kiln is 500 barrels.
150-foot kiln is 750 barrels.

The writer is informed on good authority that the amount of fuel in the form of pulverized coal required to properly calcine enough clinker to make a barrel of cement in a

60-foot kiln is 110 pounds.
80-foot kiln is 100 pounds.
110-foot kiln is 90 pounds.
150-foot kiln is 80 pounds.

While the above estimates are approximate, and may vary somewhat in different mills and under varying conditions, it is obvious that up to a certain limit at least, the lengthening of the kiln results in an economy of fuel. To what limit this lengthening process could be profitably carried in acutal practice is apparently undetermined. The general opinion which seems to prevail among practical cement makers is that in the 140- or 150-foot

kiln this limit has been reached. The cooled clinker is a hard, semivitrified, lumpy to finely granular, dark greenish-gray substance when properly burned. When insufficiently burned it is brownish in color.

The grinding of the clinker constitutes what is known as the finishing process and is accomplished in the same way as the grinding of the raw materials. The first step in the reduction of the clinker is accomplished in the ball mills. From them it is fed to tube mills. On emerging from these it should be so fine that 90 per cent. will pass a 100-mesh sieve. In color it should be cold bluish-gray, not brown, and should have a specific gravity, when freshly ground, of 3.0 or 3.1. After grinding, the finished product is conveyed to the stock house where it remains in bins for a few weeks or months to "ripen." This ripening process consists of certain chemical changes, the most important of which is the hydration or slacking of the relatively small percentage of free lime almost invariably present. It may also absorb a certain amount of carbonic acid, the amount of the absorption of this gas depending upon the opportunity it has for so doing. This results in a slight lowering of the specific gravity. During a period of six months Portland cement may lose from 4 to 7 per cent. of its original weight and then may have a specific gravity of 2.9, but it ought not to fall below this. Should it do so the fact is usually interpreted as meaning too much uncombined or free lime, which may mean either an over-limed or under-burned cement. Other things being equal, the more thorough the burning the higher the specific gravity, the maximum being 3.15 in well-balanced mixtures.

During the entire process of manufacture a most careful watch is kept upon the chemical composition of both the raw and the finished materials. Frequent chemical analyses of average samples from the quarry are necessary to determine how much limestone or clay must be added. The mud from drill holes is used as an index of the average of the quarry.

VARIETIES OF CEMENT OTHER THAN PORTLAND.

Besides Portland cement a considerable amount of Natural or Rosendale cement was formerly manufactured in the Lehigh region, but owing to improved methods in the manufacture of true Portland cement, it has bas been very nearly displaced by the latter. This variety is made by burning the rock just as it comes from the quarry in vertical kilns at a temperature only great enough to drive off the carbonic acid, in the same way that limestone is burned in making lime, and then pulverizing the burned product. The resulting "Natural cement" is quick setting but slow in hardening and never attains the strength of true Portland. For underground or underwater construction, where a rapidly setting cement is required and where great strength is not necessary, it may serve the purpose quite as well or possibly better than Portland. The amount at present manufactured, however, is small.

The rock used in the manufacture of natural cement is low in lime, having usually not more than 60 to 70 per cent. $CaCO_3$, and is taken from those beds in the Trenton limestone series which lie well up toward the overlying slates.

By mixing three parts of natural cement with one of Portland an intermediate variety is produced called "Improved Natural Cement," which is materially stronger than the natural. This grade is made by grinding together three parts of the burned natural cement rock and one part of clinker from the rotary kilns.

TESTING THE PROPERTIES OF CEMENT.

It is not alone sufficient that cement should come up to the standard as regards chemical composition, for it might satisfy all of the conditions of a rigid chemical examination and still be faulty as a constructive material. This might result from an improper blending of the raw materials or from insufficient burning, or again, from imperfect grinding of the clinker.

In order to be accounted thoroughly safe and capable of performing its responsible mission, it should be made to stand the following additional tests: (1) Setting properties, (2) soundness, (3) strength, (4) specific gravity, (5) fineness.

1. *Setting Properties.*—These, while not of the very first importance, are essential. There may be and in fact nearly always is considerable variation in the time of set between different brands of cement or, for that matter, between different samples of the same brand, one of the difficulties in manufacture being to bring this variation within the usual specification limits.

Initial and Final Set.—The setting time of cement is commonly determined by means of the so-called Gilmore Needles (a method proposed by General Gilmore, U. S. A.). The apparatus consists of two vertically placed needles or wires, properly supported so that they can be raised and lowered. The larger of the wires is one-twelfth inch in diameter and is weighted with a one-fourth pound weight. The small is one-twenty-fourth inch in diameter and is weighted with a one pound weight.

A partion of cement is moistened with just enough water (which should have a temperature of from 60° to 70° F. and which in quantity is about 20 per cent. by weight of the sample taken) to make it cohere and is then made into a thin cake upon a piece of window glass usually four or five inches square. The cake or "pat," as it is called, is about three inches in diameter and one-half inch thick at the center and thins away at the edges. When the pat will support the one-twelfth inch wire weighted with the one-fourth pound weight it is said to have acquired its "initial set," and likewise when it will support the smaller needle with the greater weight it has acquired its "final set."

According to standard specifications, Portland cement must develop initial set in not less than thirty minutes but must develop final set in not less than one hour, nor more than ten hours.

For natural cement the initial set should develop in not less than ten minutes and final set in not less than thirty minutes nor more than three hours.

2. *Soundness.*—This is the most important property of Portland or natural cement, but unfortunately is perhaps the most difficult to determine with absolute certainty.

Portland cement is considered sound or constant in volume after successfully undergoing the following tests:

Three pats are made of which one is kept in air at normal temperature and observed at intervals for at least twenty-eight days; the second is kept in water at as near 70° F. as practicable and observed at intervals for the same period of time. The third is exposed in an atmosphere of steam above boiling water in a loosely closed vessel for five hours. If these pats at the end of these periods of time remain hard and firmly attached to the glass (*i. e.,* do not curve and leave the glass) and show no signs of distortion, cracking, checking or disintegrating, the cement is pronounced sound.

3. *Strength.*—The object here is to determine as accurately as possible the strength which a given cement will develop within a certain period of time and by comparing its increase of strength as shown at the different dates of testing, to arrive at some conclusion as to its ultimate strength. For this purpose a weighed sample is mixed with just enough water (usually about 20 per cent.) to render it plastic and then packed into moulds, which in ground section are sheaf-shaped and which at the center have a cross-section of one square inch. These moulded samples are called "briquettes" and a single form or mould usually holds five briquettes. A great deal depends upon the skill of the operator in the making of briquettes and in the hands of different operators a wide variation in results may be expected. In other words, the personal equation enters so largely into the problem that cement testing in this particular phase, is in a very unsettled state, at least in so far as scientifically accurate and uniform results are concerned.

The briquettes are prepared in two ways, viz.: by mixing pure cement (neat briquettes); or by mixing one part cement with three parts of standard sand, which is a uniform article especially prepared for the purpose (sand briquettes).

The briquettes thus made are allowed to set one day (twenty-four hours) in moist air and after that are immersed in water. At periods of one, seven and twenty-eight days they are broken by tension in machines especially constructed for that purpose (of which the most common in use are the fairbanks, the Olsen and

the Riehle) and the tensile strength in pounds per square inch determined. The minimum strength required in order to satisfy the usual standard specifications, which strength must never show retrogression, may be expressed as follows:

NEAT CEMENT.

Age	Strength per sq. in.
1 day (in moist air)	150–200 pounds.
7 days	450–550 pounds.
28 days	550–650 pounds.

1 PART CEMENT, 3 PARTS SAND.

Age.	Strength per sq. in.
1 day	150–200 pounds.
28 days	200–300 pounds.

The following table gives an idea of the relative strength of Portland, improved natural and natural cement.

	1 Day.	7 Days.	28 Days.	3 Mos.	6 Mos.	1 Year.	2 Years.
Portland (neat) pounds	300	730	840	875	895	900	920
Improved " "	100	230	360	450	550	520	540
Natural " "	85	130	190	305	350	380	415
Portland (1 : 2) "		300	400	450	480	505	500
Improved (1 : 1) "		220	360	540	670	680	715
Natural (1 : 1) "		65	115	210	265	275	290

As will be observed in the second table, improved cement shows a greater actual strength when mixed with sand than when mixed neat.

According to standard specifications natural cement must show a minimum strength, with no retrogression of the same, as follows:

NEAT.

Age.	Strength per sq. in.
1 day	50–100 pounds.
7 days	100–200 pounds.
28 days	200–300 pounds.

1 PART CEMENT, 3 PARTS SAND.

Age	Strength per sq. in.
1 day	25– 75 pounds.
28 days	75–150 pounds.

4. *Specific Gravity.*—The specific gravity of Portland cement has already been referred to and as stated should not fall below 3.1. For natural cement 2.8 is the minimum.

5. *Fineness.*—Standard specifications require that Portland cement must be ground to a fineness such that it will leave by weight a residue of not more than 8 per cent on a 100-mesh sieve.

The same regulations require that natural cement shall leave a residue of not more than 10 per cent. on a 100-mesh sieve and not more than 30 per cent. on a 200-mesh sieve.

GENERAL REMARKS ON SOME SPECIAL METHODS OF SAMPLING AND TESTING DURING PROCESS OF MANUFACTURE.

The cement when ground runs into large bins holding in some mills 1,500, in others 2,000 barrels. Samples are taken all over the surface of the bin at least once every two hours by means of a long-handled spoon or ladle and all are thoroughly mixed. These two-hourly samples are so combined as to yield just 10 samples when the bin is full. For example, if 40 hours continuous grinding is required to fill a bin, all samples taken during each four hours are thoroughly mixed, resulting in 10 samples for the whole bin. Each sample thus represents 150 (or 200) barrels. Samples are placed in a sample-box holding about 10 pounds and labeled (bin A, sample 1, etc.).

Each sample is mixed or "gauged" in its proper order. Ordinarily 45 ounces of cement are mixed with 21 per cent. of water, though the amount of water added varies with different cements and even with different samples of the same bin.

The paste is mixed or gauged for five minutes with a trowel on a smooth surface (slate, marble or glass slab) and then moulded into nine briquettes by pressing into the moulds with the fingers.

When the 10 samples have been moulded, an average sample is made by taking equal parts of each of the 10 samples and mixing them thoroughly. This average sample is also moulded into nine (or more) briquettes. When the moulding is com-

pleted there will be 10 sets (11, including the set made from the average sample) of briquettes containing nine each. From each set three briquettes are broken in 24 hours, three in seven says and three in 28 days and a careful record kept.

In the same way the briquettes made from the average sample are broken and the results recorded. Usually briquettes enough are made from this average sample to be broken at the additional intervals of three and six months, and one, two, three, four and five years.

All briquettes are stored in tanks in which the water is changed daily during the summer and twice each week during the winter.

SOUTHERN EXTENSION OF THE KOOTENAI AND MONTANA COAL-BEARING FORMATIONS IN NORTHERN MONTANA.[1]

CASSIUS A. FISHER.

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INTRODUCTION.

The object of this paper is to set forth the result of recent observations made on certain coal-bearing formations in southern Montana and northern Wyoming, and their correlation with formations in northern Montana which have been studied in a detailed way by Stanton, Hatcher, Newberry, the writer and others. In previous investigations of the geology of southern Montana and northern Wyoming no attempt has been made to fix stratigraphically the line between the Lower and Upper Cretaceous rocks, the term Cloverly being applied to all sediments lying between the top of the Morrison and the base of the Colo-

[1] Published by permission of the Director of the U. S. Geological Survey.

rado formations. Similarly, no subdivisions of the Montana had been recognized in this region, the entire group having been included in the so-called Pierre, Fox Hills and Laramie formations.

During the summer of 1906, while engaged in a detailed survey of the coal deposits of the Great Falls region for the purpose of the classification of the coal lands, under the general supervision of Mr. M. R. Campbell, a special study was made of the Kootenai formation, which contains the only workable coal bed in the field. Fossils were collected from a number of different horizons which not only verified the Kootenai age of these rocks, but proved that the Kootenai formation is thicker in this region than previously supposed. During the past season more extensive surveys of coal deposits in central Montana and northern Wyoming by parties of the United States Geological Survey, with which the writer was associated, afforded an excellent opportunity for a regional study, not only of the Kootenai, but also of the Upper Cretaceous, especially the subdivisions of the Montana group, in the lower part of which valuable coal deposits are found. In this regional study, which extended across southern Montana and northern Wyoming, a number of detailed sections were measured of the Kootenai formation, fossils collected, and a careful study made of the sequence of the beds. By this means it was possible to trace the formation southeastward from the Great Falls region to the southern part of the Bighorn basin in Wyoming. In a similar manner the subdivisions of the Montana group, the Eagle, Claggett, Judith River, and Bearpaw formations, as worked out by Stanton and Hatcher[1] in the Missouri River region of central Montana, were definitely recognized as far south as the Montana-Wyoming line.

DESCRIPTION OF FORMATIONS.

KOOTENAI FORMATION.

General Statements.—The name Kootenai, after a tribe of Indians who hunted in the southern Canadian Rockies, was first proposed in 1885 by Dr. George M. Dawson, to apply to beds

[1] Stanton, T. W., and Hatcher, J. B., Bull. No. 257, U. S. Geol. Survey, 1905.

consisting of sandstones, shales, and shaly sandstones in which there are occasional layers of conglomerate, also a zone of workable coal beds. The area originally described was located along the Rocky Mountain front range in Alberta, between the forty-ninth parallel and Medicine Bow River, including an area about 140 miles long and 40 miles wide. Plants collected from this locality were reported on by Sir William Dawson, who gave twenty-two forms, including new species in four different genera. In the first publication in which the formation receives its name, and where a list of fossils from the beds is given, the following statements concerning the age of the beds are made by Sir William Dawson: "The Kootenai series should probably be placed at the base of the table as a representative of the Urgonian or Neocomian, or at the very least should be held as not newer than the Shasta group of the United States geologists and the lower sandstones and shales of the Queen Charlotte Islands. It would seem to correspond in the character of its fossil plants with the oldest Cretaceous floras recognized in Europe and Asia, and with that of the Kome formation in Greenland, as described by Heer."

In 1887, two years after the formation was described by Sir William Dawson in the Canadian regions, Dr. J. S. Newberry found fossil plants in the coal-bearing rocks of the Great Falls region, which enabled him to make the definite statement that these rocks were of the same age as those north of the International Boundary Line, described by Dr. George M. Dawson, and designated the Kootenai series. Following this first discovery by Dr. Newberry, additional fossil plant collections were made from these coal-bearing rocks of the Great Falls region by Messrs. Peale, Knowlton, Weed, Ward, and others, which materially increased the number of species from this locality. Prior to the investigation of this region by Weed,[1] no attempt had been made to give a stratigraphic limit to the beds of Kootenai age in this locality, the chief interest being centered on the descriptions of the flora and the correlation of the rocks in which it was found with other localities, although fossil plants had been collected

[1] Weed, W. H., Geologic Atlas, U. S. Geol. Survey, folio 55, 1899.

from more than one geologic horizon. In Weed's report, about 300 feet of beds, constituting, what he called, the Cascade formation, were regarded as of Kootenai, or Lower Cretaceous age. During the field season of 1906 large collections of fossil plants were made by the writer at various horizons, which demonstrated that the Kootenai rocks of the Great Falls region are not only thicker than previously supposed, but that they probably constitute all the sediments between the Morrison formation and Colorado shale in the vicinity of Great Falls, and that the Dakota, or lowest member of the Upper Cretaceous, is probably absent from this district.

Great Falls Region.—In the Great Falls region the Kootenai formation consists of alternating layers of gray, medium to coarse-grained pebbly sandstone and red, sandy shale and clay, with the sandstone predominating, especially in the lower half. Limestones, generally concretionary, occur at different horizons throughout the formation. The sandstones vary in thickness from 10 to 90 feet, and are more or less massive in character. In the upper part the red shale predominates and is interbedded with thin layers of impure sandstone. The succession of beds in the Kootenai formation, compiled from exposures on both the east and west sides of Belt Creek at Belt, is given below:

SECTION OF KOOTENAI FORMATION AT BELT, MONT.

	Feet.
Shale, red, somewhat arenaceous, with thin-bedded sandstone members in lower portion	190
Limestone, light, brown, compact, fossiliferous	5
Shale, reddish, arenaceous, and sandstone, red, laminated; shale predominating	29
Sandstone, gray, weathering light brown; coarse-grained, massive,	13
Concealed	19
Sandstone, gray, pebbly, massive	5
Partly concealed; grayish clay in lower portion	4
Sandstone, lilac-colored	6
Concealed	7
Shale, red and purple	11
Sandstone and shale, red, in alternating layers	11
Sandstone, gray, iron-stained, massive	19
Partly concealed; probably red shale	55
Limestone, gray	2½

	Feet.
Shale, green, sandy, containing layers of impure sandstone	3
Sandstone, gray, massive, cross-bedded	21
Clay and carbonaceous shale in alternating layers	6
Coal	6½
Concealed	60
Total	473

On the north side of Skull Butte, a small laccolithic uplift about 6 miles south of Stanford, Montana, which is located about 35 miles southeast of Belt, the following section of the Kootenai formation was measured:

SECTION OF KOOTENAI FORMATION ON NORTH SIDE OF SKULL BUTTE, MONT.

	Feet.	Inches.
Shale, reddish, sandy		
Sandstone, gray, thin-bedded	1	6
Shale, reddish, sandy, with layers of sandstone in lower part	21	
Sandstone, greenish-gray, weathering dark, thin-bedded above, clay-ball conglomerate below	4	
Shale, reddish, sandy, with layers of sandstone in lower part	27	
Sandstone, gray, cross-bedded, clay-ball conglomerate in lower part	5	6
Shale, reddish, sandy	30	
Sandstone, soft, thin-bedded	20	
Sandstone, gray, massive, clay-ball conglomerate	3	6
Shale, red, sandy	38	
Sandstone, gray, massive, clay-ball conglomerate	5	
Shale, red, sandy	24	
Sandstone, calcareous, alternating with sandy shale	20	
Sandstone, light and dark gray, massive, fine-grained	86	
Coal	6	(Est.)
Sandstone, gray, massive, soft	62	
Total	353	6

Judith Basin Region.—The Kootenai formation in Judith basin, which lies about one hundred miles southeast of the Great Falls coal field, is composed of alternating light-colored massive sandstones and reddish shales with occasional calcareous concretionary members. As a rule the sandstones are not persistent, and often thin materially within a short distance. Where coal occurs in the Kootenai it is usually found in close association

with and immediately underlying the lowermost sandstone, which is the most persistent member of the formation. In thickness the Kootenai is fairly uniform throughout the Judith Basin, being approximately 550 feet. Plant remains of the Kootenai formation in the Judith Basin region have only been obtained in a few localities, but the collections contain a sufficient number of well-chosen species to establish the age of the formation in this region. The succession of the beds in the Kootenai formation at two different localities in the Judith Basin region, namely, at the head of Muddy Creek, west of Garneill, and on the east slope of the South Moccasin Mountains, are given in the following sections, measured by W. R. Calvert and the writer:

SECTION OF KOOTENAI FORMATION AT THE HEAD OF MUDDY CREEK, 7 MILES WEST OF GARNEILL, MONT.

	Feet.
Shale, maroon, sandy, with an occasional thin sandstone layer	200
Sandstone, gray, weathering tan, coarse-grained	8
Shale, maroon, sandy	60
Sandstone, gray, coarse-grained, weathering irregularly, and containing woody fragments	25
Shale, maroon, sandy	72
Sandstone, gray, massive, pebbly	50
Partly concealed; consisting of sandstone members in upper part	42
Shale, grayish-brown, compact	6
Coal	3
Concealed; probably greenish sandy shale	87
Total	553

SECTION OF KOOTENAI FORMATION ON EAST SLOPE OF SOUTH MOCCASIN MOUNTAINS, MONTANA.

	Feet.
Partly concealed, red soil	50
Sandstone, light-colored, coarse-grained, clay-ball conglomeratic	10
Shale, maroon, argillaceous	16
Sandstone, white, soft, cross-bedded	12
Concealed	10
Sandstone	3
Shale, maroon, argillaceous	6
Sandstone	2
Shale, maroon argillaceous	30
Sandstone, light-colored, medium-grained, cross-bedded	18

	Feet.
Shale, maroon, argillaceous	20
Sandstone, light-colored; lower 3 ft. contains small clay-balls	15
Shale, maroon, argillaceous	26
Sandstone, thinly bedded	10
Shale, maroon, containing yellowish clay concretions	15
Sandstone, light-gray, fine-grained, massive, calcareous at top	6
Shale, maroon, with several calcareous members containing clay pebbles	23
Sandstone, white, soft, medium-grained	3
Shale, maroon and light-colored; sandy	6
Sandstone, coarse-grained to pebbly; pebbles chiefly feldspathic with a few dark limestones up to 1 inch	1
Shale, gray sandy	4
Sandstone, gray, coarse-grained to pebbly; cross-bedded	60
Shale; dark, carbonaceous, with thin coal beds	10
Concealed	80
Shale, dark gray	1
Sandstone, iron-stained, calcareous	1
Limestone, argillaceous to sandy, without bedding, and weathering into concretionary forms	2
Shale, light-gray, sandy, upper 2 ft. dark-bluish	8
Total	448

Musselshell River Region. — Along Musselshell River the only locality where rocks occupying the position of the Kootenai were examined was on the south side of a small uplift which is structurally a spur of the Little Belt Mountains, located about six miles west of Martinsdale, Mont. Here exposures were not sufficiently good for a detailed measurement of the formation, but the salient stratigraphic features could be recognized, viz., reddish sandy shale above, alternating with thin sandstone members and massive coarse-grained pebbly and conglomeratic sandstones below, followed in descending order by sandy shale and finally highly colored variegated shale and sandstone, presumably Morrison. The coal bed which might be expected below the pebbly conglomeratic sandstone was not observed in this section, probably owing to poor exposures. Farther east on the south side of Musselshell River near Widdicombe's ranch, there is a small dome-shaped uplift which exposes a part of the supposed Kootenai formation, but no fossil plants were found at this locality, and as only a part of the formation is exposed, no section is here introduced. The rocks consist of red sandy shale

with many iron concretions and highly ferruginous sandstone layers. Lithologically the beds exposed resemble the red shaly members of the Kootenai formation farther north.

Bighorn Basin Region.—In the Bighorn Mountain district of northern Wyoming, about 125 miles south of the Musselshell River, rocks of similar lithologic character and holding the same stratigraphic position, have been designated the Cloverly formation by Darton[1] and later used in the same sense by the writer.[2]

The Cloverly formation in the Bighorn Basin region presents considerable variation in stratigraphy and thickness. In many places a portion of the formation is absent, owing to an erosional unconformity which exists between the Cloverly and overlying Colorado. In certain places, however, for example, on Gypsum Creek and near Thermopolis, the greater part of the formation appears to be present. Wherever the Cloverly formation is typically developed it consists of a massive coarse-grained, cross-bedded, often pebbly sandstone, overlain by maroon sandy shale in which occur bands of chert and sandy material. Above the maroon shale there is another massive cross-bedded tan-colored sandstone which is not so coarse-grained as the basal member of the formation. This sandstone in places is overlain by a few feet of dark-red sandy shale, followed by alternating layers of rust-colored sandstone and sandy shale, the lower part of which should probably be included in the Cloverly formation.

On the south side of No Wood Creek, about 30 miles above its mouth, and 2 miles south of Bell's ranch, there is an exposure of the Cloverly formation which is of unusual interest in the present discussion. The dips are low at this locality and the conditions not favorable for a careful measurement of the thickness of the beds. It is therefore impossible to state just how much of the formation is present, but it is reasonably certain that a part of it is absent, having been removed by erosion. About 100 to 125 feet above the contact of the Cloverly and Colorado formations at this place there occurs a bed of dull colored luster-

[1] Darton, N. H., Prof. Paper No. 51, U. S. Geol. Survey, 1906.
[2] Fisher, C. A., Prof. Paper No. 53, U. S. Geol. Survey, 1906.

less coal of workable thickness which is said to continue for several miles to the south, although it has only been observed by the writer at this locality. In dark-colored shale immediately above this coal bed a small collection of fossil plants was obtained by the writer, which have been studied by Dr. F. H. Knowlton, who pronounces them as of undoubted Kootenai age. About 75 miles farther south, in the southern end of Bighorn Basin near Thermopolis, E. G. Woodruff measured a section of the Cloverly formation, which consists of a heavy basal sandstone member overlain by reddish sandy shale which is followed by another sandstone of slightly less prominence. Sections of the Cloverly formation which were measured on Gypsum Creek and near Thermopolis, points in the extreme north and south ends of the Bighorn Basin, are given below:

SECTION OF CLOVERLY (KOOTENAI) FORMATION ON GYPSUM CREEK, 15 MILES EAST OF FRANNIE, WYO.

	Feet.
Sandstone, rust-colored, alternating with dark shales, containing fresh-water shells	—
Shale, dark purplish	15
Sandstone, gray, massive containing a layer of chert pebbles	70
Concealed; probably shale	25
Shale, bluish, with many limestone concretions containing chert in the lower part of shale	70
Shale, deep maroon	12
Sandstone, pure white, sugary	2
Shale, red, sandy, with gypsum	23
Sandstone, thin-bedded, containing many small pebbles of chert about ¼-inch in diameter	40
Sandstone, strong, hard, bluish-gray, weathering pink and brown; stained red in places; leaf-bearing	50
Total	307

SECTION OF CLOVERLY FORMATION, 3½ MILES NORTH OF THERMOPOLIS, WYO.

	Feet.
Sandstone, gray, massive, weathering tan	9
Shale, blue and drab	9
Sandstone, thin-bedded	5
Shale, variegated	40

	Feet.
Sandstone, light-colored, massive, cross-bedded, with lenses of conglomerate throughout; conglomeratic at base; varies in thickness locally	38
Shale, greenish brown	59
Sandstone, yellowish gray; massive at base; argillaceous in upper portion	130
Total	290

Summary.—The salient stratigraphic features of the Kootenai formation of the Great Falls region are two more or less prominent sandstone members, separated by a red sandy shale in the lower part of the formation, and red shale containing a few thin sandstone beds above. Beneath the lowest prominent sandstone, the workable coal bed occurs underlain by soft sandy shale. The tripartite arrangement of sandstone, red shale, and sandstone in the lower half of the Kootenai formation is a very characteristic stratigraphic feature in the Great Falls and Judith basin region; also farther south in the Cloverly formation of the Bighorn Basin region, as is shown by the accompanying geologic sections of these different localities. The red shale, alternating with thin beds of sandstone, which make up the upper part of the Kootenai in the Great Falls region, appear not to be present in the Bighorn Basin. The absence of this upper member may possibly be accounted for by an erosional unconformity which exists between the Cloverly and overlying Colorado formations, and which in places is believed to have removed a considerable part of the Cloverly.

In the Great Falls region a workable coal bed is found in the lower part of the formation with which is associated plant-bearing, carbonaceous shale of Kootenai age. The same is true of the Cloverly in certain parts of the Bighorn Basin region, as demonstrated by the exposures south of No Wood Creek, where plants of Kootenai age are found in shale immediately above the coal. The presence of these plants establishes the correlation of that part of the Cloverly with the Kootenai formation farther north.

The coal-bearing zone of the Kootenai formation on the west side of the Rocky Mountains, in Alberta, has a thickness of

2,800 feet and contains fourteen possibly workable coal beds. On the east side of the range, where the measures of the Kootenai are very much thinner, they still carry a number of workable coals. In the Great Falls region farther south on the same side of the Rocky Mountain uplift, only one workable coal bed occurs, which in places is separated into two members with a few feet of shale between. In two localities in the Great Falls field a coal bed, a few inches thick has been observed near the top of the Kootenai formation. Coal of workable thickness is not continuous at the main coal horizon in this region, but thins out in places, causing the deposits to occur in certain areas with barren measures between. Farther east in the Judith basin the coal bed is thinner and of poor quality, and the coal areas are more separated. To the southward the coal bed of the lower part of the Kootenai diminishes and in the Musselshell River region, wherever the formation was observed, the coal appears to be absent. Still farther south in the northern part of the Bighorn Basin region, the Cloverly is not coal-bearing in its lower part, but to the southeast, in the exposures near No Wood Creek, coal reappears in the lower part of the formation in a bed of workable thickness. The coal of the Great Falls, Judith Basin, and southern Bighorn Basin regions is believed to be at the same horizon, and it possibly occupies about the same position as the Cambria and Hay Creek coals of the Black Hills district, which occur in rocks of Lower Cretaceous age.

MONTANA GROUP.

General Statements.—The name Montana was first used as a group term by the late George H. Eldridge[1] to include the Fort Pierre and Fox Hills formations in the vicinity of Denver, Colorado. Later it was discussed by Stanton[2] and applied in a similar sense by Cross[3] in the same general region, and still

[1] Eldridge, George H., *Am. Jour. Sci.*, 3d ser., vol. 38, 1889, p. 313.
[2] Stanton, T. W., Bull. 106 U. S. Geol. Survey, 1893, pp. 18, 47–52.
[3] Cross, Whitman, Geologic Atlas U. S., folio No. 7, U. S. Geol. Survey, 1894.

later by Eldridge,[1] Iddings and Weed,[2] Weed and Pirsson,[3] Hague,[4] and others, farther north in Wyoming and Montana. In 1903, as above stated, a detailed study was made by Stanton and Hatcher[5] of the Upper Cretaceous rocks along Missouri and Milk rivers in north-central Montana. The object of this investigation was primarily to determine the position and stratigraphic limits of the Judith River beds in this region. It led, however, to a regional study of the stratigraphy of the Upper Cretaceous in northern Montana, and the recognition of four well-defined subdivisions of the Montana group, namely, the Eagle, Claggett, Judith River and Bearpaw formations. The first two and last are mostly marine, while the Judith River is a fresh-water formation with thin brackish-water beds.

Judith River Region.—Along the Missouri near the mouth of Judith River, where Stanton and Hatcher made a careful study of the Judith River beds, local uplifts occur which expose within a radius of a few miles the entire Montana group. Here the Eagle formation, as described by the above authors, "consists of laminated sandstones and shales, grading down through 30 or 40 feet into the underlying formation, but its most conspicuous member is a heavy bedded or massive, very light yellowish or white cross-bedded sandstone, 100 feet or more in thickness," which weathers into cliffs or steep slopes. "Above the massive white sandstone occur softer beds consisting of sandstone, shales, and many beds and seams of lignites."[6] The total thickness, including the softer beds above, which are here assigned to the formation, is 300 feet. Above the Eagle there are about 400

[1] Eldridge, George H., Bull. 119, U. S. Geol. Survey, 1894, pp. 23–24.

[2] Iddings, J. P., and Weed, W. H., Geologic Atlas U. S., folio 1, U. S. Geol. Survey, 1894.

[3] Weed, W. H., and Pirsson, L. V., Bull. 139, U. S. Geol. Survey, 1896, pp. 47–48.

[4] Hague, Arnold, Geologic Atlas U. S., folio No. 30, U. S. Geol. Survey, 1896.

[5] Stanton, T. W., and Hatcher, J. B., Bull. 257 U. S. Geol. Survey, 1905, pp. 1–174.

[6] The original description by Weed gives about the same limits to the formation at the type locality near the mouth of Eagle Creek on the Missouri about 25 miles above Judith. Geologic Atlas, U. S. Geol. Survey Folio 55, 1899.

feet of beds "consisting largely of dark clay shales with variable intercalated bands and beds of sandstone, especially in the upper half," to which Stanton and Hatcher have applied the name Claggett, after old Fort Claggett, where the formation is well exposed. Marine fossils occur at several horizons, especially in calcareous concretions which abound in dark shales of the lower part of the formation, also the yellow sandstones higher up are often locally very fossiliferous.

Overlying the Claggett formation is the Judith River beds which is composed of "light ash-colored sandstones alternating with usually darker colored and more friable shales and clays, mingled with frequent seams of lignite." The lignite beds, especially those near the top of the formation, in places attain considerable thickness. The most persistent one of these lignite beds occurs very near the top of the formation, and is frequently overlain by a shell breccia consisting mainly of *Ostrea subtrigonalis*. The formation has an average thickness of about 500 feet.

The next formation in ascending order is the Bearpaw shale, so named from the Bearpaw Mountains, around which it is well exposed. It consists of uniformly dark clay and shale, which weather into rounded slopes. Calcareous concretions occur throughout the formation, most of which are fossiliferous, yielding a varied marine invertebrate fauna. The thickness of the Bearpaw in this region is estimated at about 650 feet. On the east side of Cow Creek, a tributary of the Missouri, Stanton and Hatcher obtained a section of Judith River, Claggett and Eagle formations, to which is added a section of the Bearpaw shale obtained from exposures farther west.

The following section shows the succession and general characteristics of the beds in the Montana group as observed in the vicinity of Cow Creek by Stanton and Hatcher:

SECTION OF MONTANA GROUP ON EAST SIDE OF COW CREEK, MONT.

	Feet.
Bearpaw Shale (Marine).	
Clay, dark, weathering into rounded slopes; includes light-colored sand and shale at base	560

	Feet.
Judith River Formation (Fresh-water with some brackish-water beds).	
Sandstone, light ash-colored, alternating with usually darker colored and more friable shale and clay mingled with frequent beds of lignite	490
Claggett Formation (Marine with some brackish-water beds).	
Shale, light-colored, or sandy clay with band of brown sandstone containing Tancredia americana in middle. Top of marine	50
Sandstone, yellowish brown, generally soft, but with harder layers and lenses; fossiliferous	20
Shale, dark, weathering with a reddish tinge; beds are lighter toward the top and the upper 50 feet contains two beds of thin brown sandstone, each 2 to 3 feet thick	300–400
Eagle Sandstone (Mostly marine).	
No fossils; sand cross-bedded, finely laminated with thin seams of lignite	125
Sandstone; very light-colored, fine, heavy-bedded; thickness variable	40
Sandstone, buff-colored, heavy-bedded, soft at base, but harder above, with indurated lenses and numerous large concretions weathering brown at top; thickness variable	50
Sandstone, buff-colored, heavy-bedded, with lenses of lignite and shale sometimes exhibiting cross-bedding	30
Sandstone, buff-colored, regularly bedded, with several thin seams of dark shale	20

Musselshell River Region.—Along either side of the Musselshell River, which lies about one hundred miles south of the Missouri, the formations constituting the Montana group are well exposed. This region was visited by Stanton and Hatcher at the close of their investigation of the Judith River district, and sufficient paleontologic and stratigraphic evidence obtained to enable them to recognize all subdivisions of the Montana group worked out in the region to the north. During the field season of 1907 detailed surveys were made of the coal deposits of the Eagle and higher Cretaceous formations in the area lying south of Musselshell River by L. H. Woolsey and R. W. Stone, of the United States Geological Survey, with whom the writer was associated. This work afforded an excellent opportunity for a more extensive examination of the Montana group than had previously been made. Detailed sections were measured of the Eagle, Claggett, Judith River and Bearpaw formations, and fossils collected at a number of different localities. Some of these

sections were examined jointly by Drs. Stanton, Knowlton and the writer.

On a tributary of Big Elk Creek which enters that stream from the south, about one and one half miles above Big Elk post office, a careful section of the formations of the Montana group was measured and fossils collected at a number of horizons by Dr. T. W. Stanton and the writer. The Eagle sandstone at this locality consists of sandstone, sandy shale, and clay, with a coaly zone about 7 feet thick in the upper part and a 6-inch seam of coal 18 feet higher in the section. The coal in the 7-foot zone is not workable, owing to the presence of numerous shaly partings. The entire thickness of the Eagle sandstone at this place is about 370 feet, and it contains the usual prominent basal sandstone member. It is overlain by sandstone and sandy shale of the Claggett formation, occurring in alternate succession, which are not materially unlike those of the underlying formation. Marine fossils were collected from the sandstones in the lower part of the Claggett formation, which here has a total thickness of about 830 feet. Overlying the Claggett formation occur the soft sandstones and greenish-gray sandy shales of the Judith River beds. They have a thickness at this place of about 730 feet and contain fresh- and brackish-water fossils. The formation is followed in ascending order by uniformly dark shale of the Bearpaw formation, which contains iron concretions at many different horizons. Some of these contain marine fossils. A complete section of the beds measured at this place is as follows:

SECTION OF MONTANA GROUP ALONG TRIBUTARY OF BIG ELK NEAR LEBO CREEK, MONT.

	Feet.	Inches.
Bearpaw Shale (Marine).		
Partly concealed, but consisting of dark-colored shale in which marine fossils were found near middle; gives rise to pronounced valley	985	
Judith River Formation (Fresh-water with some brackish-water beds).		
Sandstone, gray and green, alternating with olive green shale	42	
Shale, greenish gray, alternating with sandstone	100	

	Feet.	Inches.
Sandstone, dark gray, alternating with shale, dull green, sandstone predominating, and weathering into strike ridges	116	
Shale, dull green, containing an occasional sandstone layer, dark colored and ferruginous	133	
Sandstone, gray, thin-bedded, soft, with an occasional shale layer; fossiliferous at base	98	
Concealed; probably consisting of soft, sandy shale with an occasional sandstone layer	194	
Sandstone, gray, iron-stained at top; thin-bedded, soft; brackish water fossils at base	50	
Claggett Formation (Marine with some brackish-water beds).		
Shale, greenish, sandy; partly concealed	28	
Sandstone, gray, thin-bedded	5	
Shale, green, alternating with thin sandstone layers	34	
Sandstone, gray, massive	10	
Shale, dark green, partly concealed	38	
Sandstone, gray, massive, shaly in lower part	228	
Shale, dull green, sandy, with an occasional sandstone layer	123	
Sandstone, gray, weathering brown, concretionary; alternating with shale, green, sandy	30	
Shale, green sandy	50	
Sandstone, gray, thin-bedded, alternating with shale, dark gray, sandy	67	
Concealed; probably soft sandy shales	84	
Sandstone, gray, weathering brown; thin-bedded, alternating with shale, gray, fossiliferous	28	
Concealed; probably soft gray sandy shale	34	
Sandstone, gray, thin-bedded, producing low strike ridge	6	
Concealed; probably consisting of soft sandy shale	47	
Sandstone, gray, thin-bedded	16	
Eagle Sandstone (Mostly marine).		
Partly concealed, mainly of dark concretionary shale with an occasional sandstone layer	37	
Shale, dark colored		5
Coal		6
Shale, dark colored		6
Sandstone, gray, soft, alternating with shale, greenish, sandy	18	
Coal, impure	7	
Clay, green		3
Sandstone, greenish gray, soft, containing an abundance of plant fragments		7
Concealed	13	
Sandstone, dull gray, soft, partly concealed	294	

Pryor Mountain Region.—Around the west and north sides of Pryor Mountain uplift, at a considerable distance from the base of the mountains, the various formations constituting the Montana group are well developed. The Eagle sandstone, which is exposed as prominent bluffs on either side of the Yellowstone River at Billings, is overlain in successive order by the Claggett, Judith River and Bearpaw formations. No section of the beds has been measured at this place, but the different formations were examined by Drs. Stanton, Knowlton, the writer and others, and sufficient fossils obtained to establish the identity of the formations. From the exposures on the south side of Yellowstone River at Billings, the writer traced the Eagle sandstone to the southeast as far as Coburn where it crosses Pryor Creek, and can be seen extending southeastward as a prominent cliff-making sandstone for a distance of 5 or 6 miles. While no attempt was made to trace this formation farther, it is believed from observations made by the writer north of Parkman and northeast of Saint Xavier Mission, that the Eagle sandstone encircles the northern end of the Bighorn uplift, and extends down the east side of that range. In traveling up the Yellowstone River Valley, west of Billings, prominent bluffs of the Eagle sandstone can be seen at some distance to the north. These can be traced as far west as Park City, where the direction of the strike changes and the sandstones cross the Yellowstone River; extend southeastward past Joliet, Fromberg and Bridger, and continue in the same direction, passing over the low divide between Pryor and Heart mountains into the Bighorn Basin. A detailed section was measured and fossils collected of the Eagle, Claggett, Judith River and Bearpaw formations at Bridger, Montana, by Drs. Stanton, Knowlton and the writer, and later another section was measured by C. W. Washburne and the writer at the north end of Elk Basin, a small anticline on the Montana-Wyoming line 35 miles southeast of Bridger. In both of these localities fossil evidence was obtained sufficient to establish the identity of all four members of the Montana group.

In the Pryor Mountain region the Eagle sandstone as exposed

in the Bridger and Elk Basin sections, consists of massive gray sandstones and sandy shales with coal beds and coaly shale in the upper part. The most prominent feature of the formation here, as elsewhere, is a basal sandstone member which weathers into a prominent cliff with two and in some places three less prominent sandstones above. The second sandstone from the bottom is slightly less massive than the basal sandstone, and between it and the one capping the formation the coaly shales and workable coal bed of the Eagle formation are found. The formation has a total thickness of about 215 feet, and contains marine fossils, especially in the lower part. It is overlain by dark sandy shale, which is here regarded as the basal member of the Claggett. Above this shale massive sandstones, alternating with dark sandy shales, continue to the top of the formation, the individual beds ranging from 25 to 75 feet in thickness. The formation has an average thickness of 435 feet, and its upper limit is marked by the discontinuance of sandstone and the occurrence of soft variegated shale and clay of the Judith River formation. In regions of low dips the latter weathers into badland forms, but when dipping steeply produces sharp ridges. Its average thickness is 370 feet, and it contains a fresh-water fauna. Immediately above the soft variegated beds of the Judith River occurs the uniformly dark colored shale of the Bearpaw formation, which here has a thickness of about 125 feet. The shale contains numerous small iron concretions and thin layers of dark ferruginous sandstone. The concretions are locally fossiliferous, bearing marine forms.

SECTION OF THE MONTANA GROUP NEAR BRIDGER, MONT.

	Feet.
Bearpaw Shale (Marine).	
Shale, dark colored, containing iron concretions and thin layers of sandstone. Both concretions and shale contain marine fossils	123
Judith River Formation (Fresh-water with some brackish-water beds).	
Sandstone, gray, soft; shale, sandy, and lignitic beds in alternating layers, the whole member being capped by 3 feet of thin-bedded brown concretionary sandstone (lig-	

	Feet.
nitic member)	45
Shale, gray, sandy, capped by 5 feet of sandstone, brown, lenticular	25
Sandstone, gray, soft, containing large iron concretions 4 to 6 inches in diameter, with lower portion overlain by greenish brown sandy shale with lignite beds, and capped by thin-bedded brown sandstone which is sometimes concretionary	24
Shale, gray, soft, sandy, capped by thin-bedded sandstone, brown	18
Concealed; probably consisting of light-colored sandy shale.	180
Shales, greenish, brownish, and bluish (sandy) in alternating layers, with lignitic beds capped by sandstone, gray, which is apparently lenticular	96
Claggett Formation (Partly marine).	
Sandstone, gray, massive, weathering into a bold cliff	40
Shale, greenish, sandy, dark at base, containing few sandstone layers	60
Sandstone, gray, massive, weathering to smooth cliffs; fossiliferous	40
Base concealed; probably soft sandstone	38½
Sandstone, gray, massive, fossiliferous at top. Typical Claggett fossils	26
Shale, dark, sandy, and sandstone, weak (in streaks 3 to 4 inches thick) in alternating layers	37
Shale, soft gray, sandy	103
Eagle Sandstone (Partly marine).	
Sandstone, gray, soft at base, hard and massive above, weathering into rounded blocks	21
Clay, light buff-colored, sandy, capped by 1 foot of thin-bedded sandstone	15
Shale, dark, coaly, and coal (with thin streaks of sandstone) in alternating layers. Beds poorly exposed. The Bridger coal probably included in this member	19
Shale, dark-gray, with deep rust-colored iron concretions	7½
Coal	2
Shale, coaly	1½
Sandstone, tan-colored	4
Sandstone, and shale, drab, sandy, in alternating layers	3
Sandstone, greenish brown	1
Shale, dark, lignitic, overlain by shale, dull-green, sandy, with deep-brown iron concretions	32
Sandstone, gray, and shale, lignitic, in alternating layers	16
Shale, gray, sandy	42
Sandstone, gray, massive, weathering into smooth, rounded ledges containing Baculites	50

SECTION OF MONTANA GROUP IN ELK BASIN NEAR CHANCE, WYO.

	Feet.	Inches.
Bearpaw Shale (Marine).		
Shale, dark	25	
Sandstone, strong, thin-bedded	30	
Shale, dark	40	
Shale, sandy, with calcareous concretions, containing marine fossils	5	
Shale, dark	30	
Judith River Formation (Mostly fresh-water).		
Shales and clays, variegated, soft, sandy, bright colors prevailing, especially light green and red; sandstone usually white. Contains Unios	350	
Claggett Formation (Partly marine).		
Sandstone, yellow, massive	40	
Sandstone, thin-bedded, and shale, sandy throughout; sandstone generally weak with few thin strong beds, some clayey shale with coal	120	
Sandstone, yellow, massive, strong	45	
Sandstone, thin-bedded, weak	75	
Sandstone, massive strong	50	
Sandstone, thin-bedded, weak	35	
Sandstone, massive, strong	25	
Shale, sandy, with thin layers of sandstone	70	
Sandstone, thin-bedded	20	
Shale, with persistent white streak 10 feet thick at the base	50	
Eagle Sandstone (Partly marine).		
Sandstone	4	
Sandstone, shaly	10	
Shale, bituminous	3	
Shale, gray	20	
Sandstone, thin-bedded	11	
Sandstone, shaly	1	9
Shale, bituminous	2	8
Shale, bituminous	7	
Coal with thin bone partings	5	6
Sandstone, shaly	3	9
Coal with shale parting near top	2	7
Shale, brown	3	8
Coal, poor, bony	3	11
Shale		6
Sandstone, thin-bedded	31	
Shale, gray, upper 20 feet are yellowish and sandy	55	
Sandstone	50	

Summary.—The stratigraphy of the Montana group in north-

ern Montana presents a number of features which aided materially in tracing out and recognizing its subdivisions farther south along the Montana-Wyoming state line, and into the Bighorn Basin. Briefly, these may be stated as follows: The prominent basal sandstone of the Eagle, usually appearing as a bold bluff above the soft Colorado shale; the presence of sandstones of similar character, although less prominent, in the overlying Claggett formation; the soft gray badlands-making sandstone and sandy shale banded with lignitic beds of the Judith River formation, and the uniformly dark valley-making clays of the Bearpaw formation. South of the state line, in the Bighorn Basin, the paleontologic evidence is as yet insufficient to establish the subdivisions of the Montana group. The most marked variation which has been observed in the various formations of this group from northern Montana to the southward, is a thinning of the Bearpaw shale from about 750 to 130 feet. While the formation is much thinner in the southern region, it still retains its lithologic characteristics of uniformly dark shale with thin sandstone layers. The other formations of the Montana group decrease slightly in thickness to the southward.

The Eagle, Claggett and Judith River formations of Montana and northern Wyoming are believed by Dr. T. W. Stanton to be the approximate stratigraphic equivalents of the Mesaverde formation farther south, while the top member or Bearpaw shale may possibly be the northern representative of the Lewis shale.

The correlation of the coal-bearing formations of the Montana group in northern Montana, with their equivalents farther south, furnishes a valuable clue to the distribution and extent of certain well-known coal-bearing zones. The Eagle formation at Joliet, Fromberg and Bridger, in southern Montana, contains a 4-foot coal bed in the upper part, which has been mined for many years, and farther south along the western side of the Bighorn Basin the Eagle is a very important coal-bearing formation, in places containing two or more workable coal beds. Farther north, in the Musselshell River region, the Eagle contains one coal bed in the upper part which, although persistent, rarely reaches a workable thickness; while still farther north, in the

Great Falls and Judith basin regions, it is not coal-bearing. Throughout the region studied, the Claggett formation contains a few thin coal beds, but they rarely attain a thickness sufficient to be of commercial importance. The Judith River formation in northern Montana contains workable coal beds and also many lignitic shales, but to the south in the Musselshell River region no coals of commercial importance have been observed, although many lignitic shales are present. Farther south, in the Bighorn Basin near Cody and Meeteetse, Wyoming, coals of workable thickness reappear in this formation, but the deposits are usually very local in extent.

RÉSUMÉ.

The most important points in this paper may be summarized as follows:

1. The Kootenai formation, which is well developed in the Great Falls region, has been followed southward through Montana into the southern part of Bighorn Basin, Wyoming, a distance of about 350 miles, where it is correlated with the Cloverly formation in which fossil plants of Kootenai age have been found.

2. Workable coals, which are so abundant in the Kootenai formation of Alberta, are found at but one horizon in the Great Falls region. Coal at this horizon thins slightly to the eastward in the Judith basin region, and disappears entirely on the Musselshell River about fifty miles farther south. It reappears, however, in workable thickness in the southern part of the Bighorn Basin.

3. The subdivisions of the Montana group as recognized by Stanton and Hatcher in northern Montana have been definitely recognized as far south as the Montana-Wyoming state line, and they possibly continue farther south into the Bighorn Basin; also around the east side of the Bighorn Mountains. The principal variations noted in these subdivisions of the Montana was the decrease in thickness of the Bearpaw shale from about 750 to 130 feet.

4. Of the subdivisions constituting the Montana group, the Eagle and Judith River are the most important coal-bearing for-

mations, the former containing valuable coal deposits throughout the Bighorn basin, and northward as far as Joliet, Montana. Farther north on the Musselshell River coals are present in the Eagle formation, but too thin to work; while in the Judith basin region, still farther north, they appear to be absent. The Judith River formation contains valuable coal deposits, also lignitic shales throughout northern Montana, but in the southern part of the State only lignitic shales have been observed. Farther south in the Bighorn Basin, however, workable coals are found in beds of local extent.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

CHARLES H. CLAPP.

METALLIFEROUS DEPOSITS.

COBALT.

Note on the Cobalt Lodes of the Transvaal. By R. BECK. Trans. Geol. Soc. of S. Africa. Vol. X., 1907. pp. 10–12, Pl. I., figs. 1–2.

Note on the Field Relations of the Transvaal Cobalt Lodes. By E. T. MELLOR. Trans. of Geol. Soc. of S. Africa, 1907. Vol. X., pp. 36–43.

COPPER.

The Braden Copper Mines in Chile. By WM. BRADEN. Eng. and Min. Jl. Dec. 7, 1907. Pp. 1059–1062, with 4 figs.

The Copper Belt of California. By H. LANG. Eng. and Min. Jl. Vol. LXXXIV., No. 20, pp. 909–913; No. 21, pp. 963–966; No. 22, pp. 1006–1010.

Mount Radiant, a New Zealand Copper Discovery. By S. FREY. Eng. and Min. Jl. Dec. 28, 1907. P. 1202, with 2 figs.

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The Marble Bay Copper Deposit. By O. E. LEROY. Mining Science. Jan. 9, 1908. Pp. 41–43.

The Poderosa Copper Mine of Collahuasi, Tarapacá, Chile. By ROBT. HACKHURST. Min. Jl. Nov. 23, 1907. P. 635. (Abstracted from "El Nacional," Aug. 11, 1907.)

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Notice geologique et minière sur le bassin cuprifère du Konilon-Niari (Congo Français). By D. LEVAL. Paris, 1907. 64 pp., with 4 plates. Price, M. 3.20.

GOLD.

Ore Deposits of the Eastern Gold Belt of North Carolina. By W. O. CROSBY. Tech. Quat. Sept., 1907. Pp. 280–286. (Reprint from Trans. A. I. M. E.)

Geology and Development of Aguacate Mines, Costa Rica. By R. A. CRESPI. Min. Wld. No. 9, 1907. 1½ pp.

The Auriferous Conglomerates of the Witwatersrand. By J. P. JOHNSON. Mining Science. Pp. 589–590.

The Witwatersrand Gold Region, Transvaal, South Africa, as seen in Recent Mining Developments. By R. A. F. PENROSE, JR. Journ. of Geol. Vol. XV., No. 8, 1907. Pp. 735–749; with 6 plates and 1 map.

The Gold and Silver-bearing Veins of Huamachuco, Peru. By F. MÁLAGA SANTOLALLA. Min. Jl. Nov. 8, 1907. P. 569. (Abstracted from Bol. d. Cuerpo de Ing. de Min. de Peru, No. 51, Lima, 1907; 66 pp., with a map and 2 views.)

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Mining in Malaya for Gold and Tin. By C. G. WARNFORD LOCK. London, England. Crowther & Goodman.

Die nutzbaren Mineralvorkommen, insbesondere die Goldlagerstätten Deutsch-Ostafrikas. By TORNAN. Monatsber. geol. Ges. 1907. Pp. 60–75.

IRON.

Geological Relations of Scandinavian Iron Ores. By H. SJÖRGREN. Bull. A. I. Min. Eng. No. 18. 80 pp.

The Iron Ores and System of Mining at Sunrise Mine, Wyoming. By B. W. VALLAT. Min. Rep., Nov. 28, 1907; 1½ pp.

The Geology and Origin of the Lapland Iron Ores. By O. STUTZER. Jl. of the Iron and Steel Inst. LXXIV., 1907. Pp. 106–206, with 7 figs. and 15 plates.

Uber die Genesis der Eisen und Manganerzvorkommen bei Oberrosbach im Taunus. By BODIFÉE. Zeit. f. prakt. Geol. Oct., 1907. Pp. 311–316, with figs. 78–83.

Die Eisenerzlagerstätten und die Eisenindustrie Württembergs. By R FLUHR. Stahl u. Eisen. 1907. Pp. 592–595, with a sketch map.

Die Eisenerzvorkommen in den Gemein den Jukkasjärvi und Gellivare im schwedischen Regierungsbezirk Norrbotten. Stahl u. Eisen. Oct. 30, 1907. 7 pp. (Abstract of a long article by W. PETERSSON.)

Récherches geoligiques sur les Gisements de Fer de Zigaze et de Komorovo. (Ovaal Méridional). By L. KONIOUCHEVSKY. With 2 maps. 2 roubles. St. Petersburg. Comité Géologique.

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Lead and Zinc Mines of North Wales. By E. WALKER. Eng. and Min. Jl. Nov. 9, 1907. Pp. 871–875, with 4 figs. and 8 plates.

MANGANESE.

Manganese in India. By L. L. FERMOR. Trans. Mining and Geol. Inst. of India. Vol. I. Pp. 69–131, with 17 figs. (Photos, wood cuts and 3 maps, scales, 1 inch = 256 miles, 1 inch = 8 miles, and 1 inch = 4 miles.)

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The Sudbury Laccolithic Sheet. By A. P. COLEMAN. Journ. of Geol. Vol. XV., No. 8, 1907. Pp. 159–182, with a geol. map and section.

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The Silver-lead Mines of Eureka, Nevada. By W. R. INGALLS. Eng. and Min. Jl. Dec. 7, 1907. Pp. 1051–1058, with 3 figs. and 15 photos.

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Tin Deposits of Cape Prince of Wales, Alaska. By A. H. FAY. Min. and Sci. Press. Dec. 14, 1907. Pp. 144–146, with 3 figs. (Abstract of paper given above.)

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Giacimenti di minerali di tungsteno a Genna Guren ai limiti fra Nurri ed Orroli (Cagliari). By D. LOVISATA. Rend. R. Acc. Lincei. (5), XVI., 1 sem, 8. Pp. 632–638, Rome, April 21, 1907.

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Asbestos and Manganese Deposits of Ilicos Norte, with Notes on Geology of the Region, Philippine Islands. By W. D. SMITH. Philippine Jl. of Science. 35 pp.

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Geology of the Virginia Barite Deposits. By T. L. WATSON. (Paper read before the A. I. M. E., July, 1907; 23½ pp.)

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CEMENT.

Ricerche chimiche per una cava di pietra da cemento. By R. SALVADORI and C. SPERONI. Gazz. Chim. ital. XXXVII., Pt. I., No. 3. Pp. 234–250. Rome, 1907.

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The Clays and Clay Industry of North Dakota. By A. G. LEONARD, E. J. BABCOCK and C. H. CLAPP. Fourth Biennial Report, North Dakota Geol. Survey. 324 pp., 36 plates, and 2 maps.

The Composition of the Red Clay. By F. W. CLARKE. Journ. of Geol. Vol. XV., No. 8, 1907. Pp. 783–789.

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Report on the Cascade Coal Basin, Alberta. By D. B. DOWLING. 37 pp., with 9 illustrations, and 4 topographic and 4 geological maps in accompanying envelope. Geol. Surv. of Canada. Ottawa, 1907.

The Geology of the Leistershire and South Derbyshire Coalfield. By C. FOX-STRANGWAYS. Mem. of the Geol. Survey, England and Wales. 6s. London. E. Stanford.

The Coal Mines of Kyūshū, Japan. By W. B. CUNNINGHAM. Min. Jl. Vol. LXXXII. Pp. 632–633, 687–688, and 720, with 2 maps.

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Die Braunkohlenablagerung von Ugljevik bei Bjelina in Nordostbosnien. By F. KATZU. Sarderabdr. a. d. Berg-u. Huttenm. Jahrb. LV. Bd. Wein, 1907. 40 pp., with 3 figs. and 1 plate.

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The Santa Clara Valley, Puente Hills and Los Angeles Oil Districts, Southern California. By G. H. ELDRIDGE and RALPH ARNOLD. U. S. Geol. Surv. Bul. No. 309. 266 pp., 41 plates.

Geology and Oil-resources of the Summerland District, Santa Barbara County, Cal. By RALPH ARNOLD. U. S. Geol. Surv. Bull. No. 321. 91 pp., 20 plates.

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Metamorphism by Combustion of the Hydrocarbons in the Oil-bearing Shale of California. By R. ARNOLD and R. ANDERSON. Journ. of Geol. Vol. XV., No. 8, 1897. Pp. 750–758, with 2 figs.

Virgin Oil Fields of Washington County (Utah). By C. W. HIGGINS. Salt Lake Min. Rev. Nov. 15, 1907. 2½ pp.

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cerning Barite Deposits. By F. J. FOHS. Ky. Geol. Surv., Bull. No. 9. 1907. 51 pp.

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Extent and Importance of Oklahoma Gypsum Deposits. By C. N. GOULD. Mining Science. Vol. LVI. Pp. 542–543; pp. 583–584.

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The Nitrate Deposits of Chile. By ENRIQUE KAEMPFFER. Min. Jl. Dec. 7, 1907. P. 693. (Abstracted from Bol. de la Sociedad Nacional de Mineria, No. 123, 1907.)

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Phosphates in the Western United States. Am. Fertilizer. Nov., 1907. 6½ pp. (Compilation of import and parts of several investigations made by the U. S. Geol. Surv. in Idaho, Wyoming, and Utah.)

PRECIOUS STONES.

Untersuchungen über einige südafrikanische Diamanten lagerstätten. By R. BECK. Z. d. Deutsch. geol. Ges. 1907. Bd. 59. Pp. 275–307, with 3 plates and 4 figs.

Beitrag zur Kenntnis der Rubinlagerstätte von Nanya-zeik. By J. J. TANATAR. Zeit. f. prakt. Geol. Oct., 1907. Pp. 316–320, with sketch geol. map.

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SALTS.

Zur Geologie der deutschen Zechsteinsalze. By H. EVERDING. Festschrift zum Leitung: F. Beyschlag. Allgem. Bergmannstage in Eisenach. I. Teil. Auch als Abhandlz. d. Geol. Landesanst. N. F., Heft 52. Berlin, 1907. Verlag der Geol. Landesanst. 133 pp., with 11 plates and 5 maps and profiles, and accompanying explanation of 30 pp.

STONE.

The Granites of Maine. By T. N. DALE and G. O. SMITH. U. S. Geol. Surv. Bull. No. 313. 202 pp. 14 plates.

SULPHUR.

El Azufre de Sechura. By J. KLINGE. Bol. de Min., Lima, Peru. Aug. 24, 1907. ½ p.

SCIENTIFIC NOTES AND NEWS[1]

SINCE THE RECENT reorganization of the Canadian Geological Survey, and the establishment of a mining branch of the Department of Mines, much work has been done in connection with ore deposits. A statement of the reports in preparation and the work accomplished during the past year will be of interest as an indication of the character of activity which the department may be expected to exhibit in the future:

1. An examination of the more promising iron ore deposits of Vancouver Island, of two of which magnetic surveys were made. This investigation was undertaken with a view to furnishing the necessary information regarding the iron ore deposits as to extent and quality in the event of the establishment of an iron industry on the coast.

2. An enquiry into the peat and lignite industry in Europe. For this purpose Mr. Nystrom was commissioned to proceed to Norway, Sweden, Denmark, Germany and Holland, to study and report upon these industries in these countries; to familiarize himself with the methods, processes and machinery employed in the commercial production of fuel from peat and lignite, and such other exploitation of peat bogs as lead to their commercial application. His report will shortly be in the hands of the printers.

3. In accordance with the provisions of Sec. 6 (a) of the Department of Mines Act, a first attempt has been made to gather material for a comprehensive report on the Mining and Metallurgical Industries of Canada.

4. Preparation for the press of the following reports on iron ore deposits:

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

(*a*) Iron ore deposits in Rainy River and Thunder Bay districts, Ontario, by F. Hille, M.E.

(*b*) Iron ore deposits along the Ottawa River, Quebec side, by Fritz Cirkel, M.E.

(*c*) Iron ore deposits in Nova Scotia, first part, by Professor J. E. Woodman.

5. Investigation of the chrome iron ore resources of the Province of Quebec, by Fritz Cirkel, M.E.; results will be incorporated in a monograph: "Chrome Iron Ores, their occurrence, development, refining and uses."

AT A MEETING of the Geological Society of Washington, held on February 26, 1908, the following papers were read: Evidences of Volcanic Activity and the Glaciers of Mt. Hood, by A. H. Sylvester; Physical Features of Peru, by Mr. G. I. Adams.

AT A MEETING of the New York Academy of Sciences, held at the American Museum of Natural History on March 2, papers were read by Mr. Robert T. Hill, "Geological Problems of the Windward Islands;" Mr. Roswell Johnson, on the "Mid-Continent Oil Fields."

THE U. S. GEOLOGICAL SURVEY announces the following publications: Bulletins:

Contributions to Economic Geology: Part II., Coal, lignite, and peat; M. R. Campbell in charge. 1907. 543 pp., 23 pls.

The above bulletin may be had as a whole or in seven parts, each issued separately. The first separate contains papers relating to coal in Pennsylvania, Kentucky, Virginia, and Alabama; the second applies to Illinois and Arkansas; the third to Montana; the fourth to Wyoming; the fifth to Colorado and Utah; the sixth to New Mexico and California; and the seventh contains general papers about fuels.

The burning of coal without smoke in boiler plants, by D. T. Randall. 1908. 26 pp.

The purchase of coal under Government and commercial specifications on the basis of its heating value, with analyses of coal delivered under Government contracts, by D. T. Randall. 1908. 27 pp.

THE LAST LEGISLATURE OF PENNSYLVANIA appropriated $50,000 for the School of Mines and Metallurgy of the Pennsylvania State College, of which sum $20,000 were for further extension of its buildings and $30,000 for its maintenance. The buildings, as planned and partly built and occupied, contain over 60,000 square feet of floor space. The buildings contain laboratories and lecture rooms, for the instruction in crystallography, mineralogy, petrography, geology, mining geology, metallography, metallurgy, assaying, ore dressing, coal washing, mining, etc.

Amongst the recent appointments are these: Clarence P. Linville, assistant professor of metallurgy; Frank A. Dalburg, instructor in mining and metallurgy; Lloyd B. Smith, instructor in mineralogy and geology; and Howard I. Smith, instructor in mineralogy and metallurgy.

The Summer School in Surveying and Mining was conducted at Canonsburg, Pa., in the mines of the Buffalo and Pittsburgh Coal Company, under the direction of Messrs. Dalburg and Smith. Later a large party of students spent the remainder of the summer at the mines of the Nipissing Company, Cobalt, Ontario.

The class graduating, in the school, in 1907, numbered twenty-six men.

J. E. SPURR and W. ROLAND COX have organized the firm of Spurr & Cox (Inc.) to conduct expert mining work in various branches. Mr. G. H. Garrey, former geologist, United States Geological Survey, and late geologist, American Smelters Securities Company, is also a member of the firm. Other engineers permanently and exclusively connected with the organization include W. D. Blackburn, topographic engineer; C. W. Doge, formerly of the United States Geological Survey; M. B. Evans and J. H. Farrell. The firm has offices in Denver, New York and Mexico City.